UNIVERSITY OF ALBERTA

GEMIDENT: A DATA BASE FOR GEMS AND SOME APPLICATIONS OF THE ELECTRON MICROPROBE IN GEM CHARACTERISATION

BY

HEIDEH OMOUMI

A THESIS

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DEPARTMENT OF GEOLOGY

EDMONTON, ALBERTA
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April 23, 1990

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Dear Heida,

Please forgive my failure to respond more promptly to your letter of April 4th.

There is no problem with the use of the items you requested, namely the diagram of the Colormaster Instrument on p. 14 of the *Colored Stone Grading Course* and the charts on pp. 2-11 with ColorMaster notations. Of course credit should be given as copyrighted so our copyrights remain in force.

Congratulations on your effective efforts in this direction. I hope you are very successful in this endeavor.

Cordially,

GEMOLOGICAL INSTITUTE OF AMERICA

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The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled: **GEMIDENT: A DATA BASE FOR GEMS AND SOME APPLICATIONS OF THE ELECTRON MICROPROBE TO GEM CHARACTERISATION** submitted by **HEIDEH OMCUMI** in patrial fulfillment of the requirements for the degree of MASTERS IN SCIENCE.

Supervisor

Date: August 6th, 1990

dedicated to my parents,

my brother Hamid, and my sister Leily

ABSTRACT

GemIdent is a literature based gemmological data base modelled after the MinIdent data base. It is a command driven program written in 25KLOC of FORTRAN and 1KLOC of Microsoft FORTRAN/C requiring 430 Kbytes of memory and it is IBM-compatible. The data base occupies 8.5 Mbytes and contains data for over 280 gem minerals at the species and variety level of classification. The data base consists of a literature compilation of optical, physical and compositional data. Optical properties comprise of refractive indices, birefringence, optic sign, dispersion, pleochroism, transparency, absorption spectra, ColorMaster colour, and fluorescence. In addition, structural and physical parameters such as symmetry, cell dimensions, density, MOHs' hardness, inclusions, collection number, cut-type, carat weight, occurrence, locality, and source reference have been included. Compositional data collected with microbeam or wet chemical techniques have also been stored in the data base.

GemIdent is the first gemmological data base which can select, sort, compare, integrate, and identify gems based on any combination of the above parameters. Comparison of gem data is primarily achieved with the DISPLAY and TABULATE commands, whereas selection and integration use

search/match algorithms. The identification of gems involves matching indices which take into account the degree of mismatch between data from unidentified samples and those available in the data base. An online HELP facility provides the necessary information on these procedures and all parameters available in the data base.

In addition to these capabilities, a heirarchial scheme of classification with division such as class, family, group etc., has been implemented for all gem minerals in the data base. An extensive synonyms list with over 700 entries, containing archaic names, trade name, and misnomers is also available.

The GemIdent data base contains the first compilation of microprobe data on gem minerals and additional data have been contributed in this study. Wavelength-dispersive techniques were used in the trace element analysis of 10 faceted ruby samples from various localities. Microprobe data are also presented for the following gem minerals: andalusite, chrome-diopside, chrysoberyl, cordierite, danburite, grossular, kunzite, prehnite, sinhalite, sphalerite, tanzanite, willemite, and zoisite.

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GEMIDENT: A DATA BASE FOR GEMS AND SOME APPLICATIONS OF THE ELECTRON MICROPROBE TO GEM CHARACTERISATION

CHAPTER 1:

GENERAL INTRODUCTION

Gemmology encompasses the study of material considered to be attractive enough for fashioning into gemstones, and use for personal adornment. The three attributes common to all such gem material are beauty, durability, and rarity. Properties contributing to the beauty of gems are colour, transparency, and "fire" (a term related to the dispersion and controlled by the details of the cut). Yet, this very beauty can be so fragile that it can be destroyed with wear, marring its attractiveness. Thus, some gems are rarely seen in items of jewelry, but highly prized by collectors. In addition to beauty and durability, the limited quantity of fine quality material suitable for faceting contributes to their rarity, which in turn results in a demand for gems. Gem materials which have been fashioned into gemstones include those of natural and organic origin, as well as man-made synthetics and imitations.

The advent of gem-quality synthetics has necessitated the application and adaptation of modern analytical techniques to the nondestructive characterisation of gem materials.

Thus, gemmology has evolved into a more quantitative and exact science. In an attempt to delineate the criteria for distinguishing natural gems from their synthetic counterparts, results obtained with various techniques have been compared to those available for natural gems. For this reason, there is currently a thrust to document chemical, spectral and optical characteristics of gems.

Traditionally comparison and retrieval of numerical data have been conducted by referral to literature sources and standard texts. It is in this capacity that the role of computers as data handlers has been realised. To fulfil this role in gemmology, a literature-based data base was envisaged. The GemIdent data base has been modelled after the MinIdent data base (Smith et al., 1989), which is a data base for minerals and a program for their identification.

The nature of the data to be included in the data base became an important consideration for computer storage and retrieval, when the contents of GemIdent were being established. Therefore, a literature review was conducted and the results are given in chapter two. This is followed by a discussion of some problems that are encountered with incorporation of all results from various methods, and for all gem materials, in one gemmological data base. In the final section of this chapter, the kinds of gem material and

the different types of data included in GemIdent are established.

In chapter three, the structure of the data base together with the various properties that have been included are discussed. In addition, a description of special facilities such as the online help feature, the classification system and the synonymy list is presented. Methods for modification of the GemIdent data base are outlined with a discussion of errors in the data base. In the final section, the only other gemmological data base is reviewed and compared to GemIdent. The applications of the GemIdent data base are illustrated with examples in Chapter four. The procedures for selection, comparison and integration of data, as well as identification of gems are presented.

In the final chapter, the application of the electron microprobe to a trace element study of ruby samples is demonstrated, and wavelength dispersive analyses of various gem minerals are contributed to the existing compositional data on gems.

CHAPTER 2:

GEM MATERIALS

INTRODUCTION

In considering which gems and properties were to be included in a gemmological data base, it became apparent that a review of different gem material together with associated gemmological data was necessary, since the nature of data is of prime importance for computer storage and retrieval. The objective of this chapter is to establish the kinds of gems and the types of associated data which are to be included in the GemIdent data base.

Gem material with the attributes of beauty, durability, and rarity, that have been fashioned into gemstones, include those of natural and organic origin as well as man-made synthetics and imitations. An important distinction must be made between synthetics and imitations: synthetics are identical man-made equivalents of naturally occurring minerals, whereas imitations are "simulations of natural or synthetic stones or fancy products made entirely or partially by man" (Brown 1985). A literature review is presented in the following section for all these gem materials. In addition, a separate section has been devoted to composite gems which can be composed of any combination of natural, synthetic and imitation gem material. Lastly, a

general review of the various methods of gemstone enhancement is presented, emphasising how the appearance and properties of gem material can be altered. The challenge of gemmology has been in the nondestructive application of various analytical techniques for the purposes of unequivocal identification of these gem materials.

In order to illustrate the variety of data that exists, emphasis has been placed on including data from the many analytical techniques that have been applied to the characterisation of such gem material. In the concluding section, a discussion of problems which are encountered with the intention of incorporating all result from various methods for all gem material in one gemmological data base are presented. The kinds of gem material and the different types of data to be included in GemIdent are also established.

GEM MINERALS

Most gems are naturally occurring crystalline minerals with a definite or range of chemical composition usually formed by inorganic processes. Out of the available 3800 mineral species approximately 250 have been used as gems. Metamict minerals with attributes of beauty, durability and rarity, which have been fashioned into gemstones (i.e., ekanite) are usually included in this group of gem materials, despite

their noncrystalline nature. Furthermore, tektites and opals are also grouped together with these gem minerals since their chemistry and occurrence are similar to minerals.

Identification of these gem minerals has largely been through determination of optical and physical properties. This has been achieved with conventional gemmological instruments such as the refractometer, polariscope, dichroscope, and direct vision hand spectroscopes. With the advent of synthetics, standard gemmological tests have had to be supplemented with more sophisticated nondestructive methods of testing. Nondestructive characterisation has been achieved with a variety of analytical techniques summarized in table 2-1.

Not only has documentation of elemental abundances taken place, but also emphasis has been placed on more accurate measurement of absorption spectra with elaborate spectrophotometers in the ultraviolet, visible and near infrared with the techniques of UV-VIS-NIR spectroscopy (Lind & Schmetzer 1983; Fritsch & Stockton 1987; Schmetzer 1989). This allowed for more detailed examination of absorption features which in turn contributed to the distinction of natural gems from their synthetic counter parts. Nuclear Magnetic Resonance (NMR) and Electron Spin Resonance (ESR) have also been used in the study of gems (Hutton 1979; Troup & Hutton 1983). These two techniques

have joined the ranks of the more sophisticated methods of testing for distinguishing between natural and synthetic origin. Application of most of these advanced analytical techniques has been limited not only by the cost of instruments involved, but also by the fact that the techniques lie outside the area of expertise of most gemmologists. Fortunately, detailed microscopic investigation of inclusions has proved to be one of the most rapid and convenient methods of gem identification, readily available to most gemmologists/jewellers, requiring only a microscope.

Standard gemmological properties commonly reported in the literature for gem minerals are: optical character (isotropic, uniaxial or biaxial), refractive indices (usually only the minimum and maximum values), pleochroism, absorption spectra (as seen with hand spectroscopes for the visible part of the spectrum), fluorescence (long and short wave ultra- violet light), density, and inclusions. Occasionally, X-ray powder diffraction techniques have been used for the determination of cell dimensions. Where chemical data is available, it has usually been obtained through XRF-EDS, SEM-EDS, EMPA-EDA and WDA techniques. Absorption spectroscopy has also been of great importance in the study of the cause of colour in gem minerals. Application of absorption spectroscopy is also effective for

answers regarding site occupancy; mainly involving transition metal elements.

Only in the past decade have chemical and spectral data become common in the gemmological literature. This level of documentation of physical, optical, and chemical properties has been a clear reflection of a necessity brought about by the appearance of gem-quality synthetics, and the need for unequivocal identification of the natural or synthetic origin.

ORGANIC GEMS

Materials used for personal adornment that have formed as a result of biological processes, are collectively called organic gems. Amongst those which are most important and commonly encountered are: pearl, coral, shell, operculum, amber, jet, ivory and tortoise shell. Details of the nature of formation, as well as chemical and physical properties of these materials may be found in Webster (1983). Various techniques have also been included for distinguishing them from their imitations and recognizing the different types of enhancing treatments used.

Some of the techniques and procedures used have been exclusively developed with a specific organic gem in mind. For example, the distinction between natural, cultured and

imitation pearls is primarily based on the different degree of transparency that each exhibits to X-rays, as viewed in X-radiographs. The presence or absence of fluorescence under the X-ray beam used in radiography can also have diagnostic value in this case. This widely practised method of distinction is important specifically for pearls.

In the case of the separation of natural amber from its simulants, small amounts of powdered material can be heated to test for the characteristic aromatic smell of amber.

The distinction of natural red coral from dyed red coral is based on presence of Fe as the colouring agent in the former. Dyed corals are free of Fe and this has been easily detected by means of an XRF-EDS spectra (Stern & Hanni 1982).

Apart from the above more specialised tests, organic gems are commonly identified on the basis of their physical and optical properties, which can be determined with standard gemmological instruments.

GEM-QUALITY SYNTHETICS

There have been many recent developments in growth techniques which are currently being used for commercial synthetic gemstone production, and while the techniques have remained essentially the same, each manufacturer has introduced relatively minor differences. Fortunately for the natural gemstone market, the production costs of synthetics remain high and therefore,a definite deterrent to large scale production. Presently, synthetics seem to fill the gap between the costly naturals and the inexpensive imitations. The distinction of synthetic gemstones from their natural counter parts has become a critical task for gemmologists.

The distinguishing criteria are related to their growth environments, which result not only in different minor and trace element content and proportions, but also varying fluid inclusions which arise from the rapid economic synthesis and from the use of different fluids. Thus, it has been necessary to supplement traditional physical and optical tests with more sophisticated nondestructive analytical techniques. However, the criteria for identification may not be completely disclosed in publications in order to avoid disclosing future developments and proprietory information. Rapid advances are being made by manufacturers to close the gap between the naturals and synthetics gem materials.

Manufacturers of synthetics have, for obvious reasons, chosen to synthesise gem materials that have great value in nature. They have had considerable success with minerals of simple composition and structure, but only imitations of such minerals as lapis lazuli and opal have been made. More details on gemstone imitations have been included in the next section.

A literature review is presented for synthetic ruby, emerald, diamond, quartz and alexandrite. These are good examples of the kinds of products that have been made with the current technology. Furthermore, they are representative of the kinds of synthetics which have caused the most problems in terms of the determination of natural versus synthetic origin. The production techniques together with the identifying criteria for each of the synthetics, have been included.

Ruby

Rubies are perhaps the most highly prized and appreciated of all coloured stones, and fittingly the first gemstone to have been synthesised by man. A comprehensive review of the gemmological properties of natural and synthetic rubies was presented by Schmetzer (1986a). Gem-quality synthetic rubies are grown from melts (flame-fusion method) or high

temperature solutions (flux-grown method). Their production techniques have been correlated with properties that are used to distinguish between rubies of natural and synthetic origin (Schmetzer, 1986b).

Synthetic rubies grown by the flame-fusion method (Verneuil method) include those known by the trade names Inamori and Bijoreve. They are identified by presence of gas-filled bubbles, curved growth striations, glide planes (plato-lines) and mosaic structures (Smith 1986; Gubelin & Koivula 1986). The invariable presence of these features makes chemical data nonessential for their identification.

In the early 1950s laser technology required ruby crystals of much higher optical quality than those produced by the flame-fusion method. Thus, flux-growth techniques were pursued and as a by product of this research effort gem-quality rubies were marketed by the mid 1960s (Nassau 1980). The classification of commercially available flux-grown rubies is based on presence or absence of various types of seeds (table 2-2). Flux-grown rubies with Verneuil seeds may have overgrowths of various thickness and partial or complete removal of this layer can occur during the faceting process. As a result, difficulty is faced in associating the various inclusions with the seed or the overgrowth, and detailed investigation of the boundary between the synthetic overgrowth and seed is necessary. The inclusions

characteristic of flux-grown synthetic rubies may be found in Gubelin and Koivula (1986).

Production techniques for flux-grown synthetic rubies also allow for a chemical approach in their identification, since crucible material (are typically Pt or Ta (Galia 1987)) and residue of fluids (compounds of Mo, Pb, W, Li and Bi) can be detected (Schmetzer 1986a,b). Trace contents of these elements have been detected by resorting to any one or a combination of XRF, EMPA, XRD and AAS (Atomic Absorption Spectroscopy) (e.g., Schmetzer and Bank 1988; Schmetzer 1987).

NAA and EMPA results of kashan flux-grown synthetic rubies, together with natural rubies from various localities were compared by Henn and Schrader (1985). Inclusions of Na rich melt residues are present in Kashan rubies, as a result of growth from cryolite melts. These rubies were easily identified with NAA, which showed increased Na content (ranging between 410-2631 ppm). In fact, this increased Na content is attributed to the peculiar inclusions, which affect the chemistry of the whole sample in NAA. With microprobe analyses, it is necessary to seek an area with surface inclusions of melt residue in order to detect the high Na content. Given the detection limits of the microprobe, the results should ideally be confirmed by

detailed microscopic investigation of such melt residues and other characteristic inclusions.

The only complete trace element study of natural and synthetic flux-grown synthetic rubies was recently conducted by Tang et al. (1988 and 1989), using the technique of Proton Induced X-ray Emission (PIXE). Table 2-3 contains the average concentrations of elements which appeared to have a relationship to the samples' origin. It was concluded that V and Fe concentrations could be used for separating natural from synthetic rubies. It was also noted that while the absence of V did not immediately imply a synthetic origin, its presence only indicated the possibility of a natural origin. Other trace elements, such as Cr, Ti, Ca, and K were found to be useful indicators of the country of origin (e.g., high Fe content, in the order of 4000 ppm, suggests that the stone may be from Sri Lanka or Thailand).

The Cr and Fe contents of Kashan synthetic rubies studied by Tang et al. (1989) and Henn & Schrader (1985) are comparable, However, in the NAA study, Na rather than Fe and V was used as the indicator element for distinguishing naturals from Kashan synthetics.

The synthesis of other coloured varieties of corundum have also been successfully accomplished through the Verneuil technique, and their identification is primarily based on

presence of characteristic inclusions (Gubelin and Koivula 1986). Flux-growth of the coloured varieties on the other hand, has been hindered by difficulties caused in crystal growth, due to addition of colouring agents. In particular, orange and blue sapphires have become commercially available on a very limited scale, and their identification is once again based on presence of characteristic inclusions (Kane 1982; Gunawardene 1984).

Emerald

There are two successful methods of synthesis for emerald. The first is the flux-growth process using fluxes such as $Li_2O + MoO_3$, $Li_2O + V_2O_5$, $PbO + V_2O_5$ etc.; and the second is through the hydrothermal growth process. Various analytical techniques have been used for the chemical distinction of these emeralds. One of the most prominent and practical methods has been through detailed microscopic examination, which in conjunction with chemical data can lead to their identification.

The chemical differences between natural and synthetic emeralds were studied and reviewed by Stockton (1984), in which the contributions by Schrader (1983) and Hanni (1982) were also included. The analytical method employed as well as a summary of results are presented in Table 2-4.

Stockton (1984) summarised the distinguishing criteria to be:

- Na_2O, MgO and FeO contents exceeds 0.1 wt% in naturals;
- Al_2O_3 > 18 wt% in all synthetics ;
- SiO_2 > 65.6 wt % in all synthetics ;
- Cl present only in hydrothermally grown synthetics.

Although the data published by Hanni (1982) agree for the most part with those of Schrader and Stockton, an inconsistency is apparent with respect to the MgO content. This was attributed to Hanni's measurements of MgO (and some other oxides) by means of EDS on the SEM rather than with the more accurate WDA facility on a microprobe. Thus, the data of Schrader is preferred to that of Hanni, despite the use of the more unconventional and destructive combination of OES and NAA techniques, which are not routinely used in gem analyses. OES is a destructive technique using an electric excitation source which causes the sample to transform into a plasma of atoms and ions. Although NAA gives accurate trace element content, it can cause radioactivity and a change in colour in emeralds (Schrader 1988).

More discrepancies and inconsistencies exist in the literature on synthetic emeralds. Table 2-5 is a compilation

of some recent compositional analyses for various synthetic emeralds. The data of Gubelin (1987a) contains significant amounts of Na_2O, MgO, and FeO for the synthetics, suggesting that the unspecified analytical method may have been semi-quantitative. Alternatively, and more importantly, perhaps a different generation of synthetic emeralds with real chemical differences was studied. Notwithstanding these discrepancies, and according to the findings of Stockton (1984), the Al_2O_3 and SiO_2 contents in all the analyses except the Russian fluxes, seem to indicate a synthetic origin. It is evident that more work is required before making a complete chemical distinction is made possible.

Two additional contributions to the distinction of natural and synthetic emeralds have employed Fourier Transform Infrared (FTIR) spectroscopy (Stockton 1987), and ESR (Troup & Hutton 1983). The spectra obtained from either of the two techniques also provide the means by which the natural and synthetic origin of emeralds can be determined.

Apart from the above cited studies, the other most important method of distinguishing natural and synthetic emerald, is through microscopic examination of inclusions. An excellent pictorial review of commonly encountered inclusions in various synthetic emeralds is presented in the " PhotoAtlas of Inclusions in Gemstone " (Gubelin and Koivula, 1986 p. 461-474). The literature is also inundated with numerous

descriptive articles on the characteristic inclusions of synthetic emeralds (e.g., Campbell and Thomas 1986; Koivula 1986; Brown and Snow 1983; Kane and Liddicoat 1985; Koivula and Keller 1985; Gubelin 1987b, 1988). Micrographs and written descriptions of inclusions have been of great diagnostic value in the distinction of natural from synthetic emeralds.

Diamond

The Diamond Research Laboratories at General Electric, De Beers, and Sumitomo Electric Industries have been able to grow synthetic diamonds which can be suitable for use as gems although their products are primarily intended for industrial applications. Only the synthetic yellow diamonds produced by Sumitomo researchers have been made available commercially and have in fact been encountered in the jewelry market (Fryer et al. 1987).

The most diagnostic property of General Electric's synthetic diamond is their reaction to a magnetic field. This is due to presence of primary iron inclusions originating from the fluxing agent. However, accurate measurement of this property requires a superconductor "SQUID" magnetometer, which is not a practical and feasible routine measurement that can be carried out by jewelers and gemmologists. Nevertheless, it is still possible to identify these

synthetics based on their characteristic fluorescence under long and short ultraviolet radiation, phosphorescence, electrical conductivity and inclusions (Crowningshield 1971; Koivula and Fryer 1984).

Sumitomo yellow diamonds are the only synthetic diamonds that are commercially available and suitable for faceting. Nitrogen content of 30-60 ppm imparts a yellow colour to these diamonds. The infrared spectrum obtained with FTIR spectrometers in the range between 1000 and 1400 wavenumbers (cm^{-1}) was found to be distinct, representing a rare type of diamond (type Ib). Most naturally occurring yellow diamonds have different spectra due to the grouping of nitrogen atoms in the structure (resulting in type Ia). Observation of the absorption spectra with conventional hand spectroscopes reveal a gradual darkening towards the violet end of the spectrum. In comparison, most near colourless and yellow natural diamonds exhibit a series of bands in the 400-500 nm range. The Sumitomo diamonds have a characteristic greenish-yellow or yellow fluorescence under short-wave UV light and are inert under long wave ultraviolet radiation. In addition, all faceted Sumitomo diamonds were observed to have an "hourglass" shaped pattern of internal grain lines visible through the pavilion, with surface grain lines on the table as well (Shigley et al. 1986).

Characterisation of De Beers gem-quality synthetic diamonds has been based on distinctive zoned pattern of colour, fluorescence in long wave UV, and phosphorescence. As for the Sumitomo diamonds, internal graining is usually present in an "hourglass" pattern of intersecting lines. Characteristic inclusions of small white pinpoints and metallic flux remains are also apparent. The infrared spectra of De Beers synthetic diamonds display only type Ib related absorption features, while in natural diamonds type Ia bands are also present. Conclusive identification requires the examination of all the properties in conjunction with one another, and the origin cannot be decided on the basis of any one property alone. The gemmological properties of these diamonds are similar to with those of General Electric and Sumitomo (Shigley et al. 1987).

Quartz

Quartz was successfully synthesised by the hydrothermal transport growth technique and it was primarily used as a frequency controller in oscillators for radio communication. However, with the rise of digital electronics, demand for electronic grade quartz decreased. Commercial production of gem-quality synthetic citrines and amethyst was achieved by

the Russians around 1975, at which point synthetic quartz started to appear on the gem market (Nassau 1987).

The hydrothermal transport growth technique involves the transport of natural quartz from solution onto a seed plate in an autoclave. The only transition metal ions which have been successfully incorporated into the quartz structure are Fe^{2+}, Fe^{3+}, and Co^{2+}. Synthetic quartz is subsequently subjected to irradiation and/or heat treatment to achieve the desired colours. For example, synthetic quartz with traces of Al can be irradiated with gamma rays to produce smoky quartz, which can in turn be heated to various temperatures to produce greenish yellow, or brown colours. Ferric iron produces the desirable yellow colour of citrine, while ferrous iron produces a green colouration in quartz. Depending on the structural site in which the iron has been incorporated, Fe-bearing quartz can be irradiated and heated to produce the amethyst colour. Thus, the actual trace element content along with subsequent irradiation and heat treatment can produce a large variety of colours in synthetic quartz (Nassau 1980).

The trace element analyses of natural and synthetic amethysts as determined by AAS have proved to be ineffective for their distinction (Lind et al. 1985). The combination of IR spectroscopy and microscopy has been used for the distinction of natural and synthetic origin (Lind &

Schmetzer 1983; Lind et al. 1985; Crowningshield et al. 1986). Natural amethysts have distinct absorption features in the 3500 cm-1 range in addition to characteristic two phase inclusions. Microscopic investigation of natural amethyst reveals sharp lamellar colour zoning and polysynthetic twinning, both of which are lacking in the synthetic counterparts. In addition, a "fingerprint" pattern on a facet of a cut stone after repolishing is only apparent in natural amethysts.

The distinction of natural and synthetic yellow and green members of the quartz family has been achieved by a combination of UV-VIS absorption spectroscopy along with microscopic investigation of structural properties (i.e., twinning, growth structures, colour zoning) and characteristic inclusions. As outlined by Schmetzer (1989), synthetic Fe-bearing citrine and green quartz lack oriented striations and polysynthetic twinning on the Brazil law. Growth structures which have developed parallel to the seed plate are also commonly observable in these synthetics. Generally, Fe-bearing synthetics are characterised by an absorption maximum in the ultraviolet with increasing absorption from red to violet in the visible part of the spectrum. In some cases, a series of weak absorption bands is present which is not found in their natural counter parts. The presence of so called "breadcrumb" inclusions in

citrines can also indicate a synthetic nature, although inclusions alone do not have a great diagnostic value.

Alexandrite

Alexandrites are amongst the most rare and valuable of all naturally occurring gems, exhibiting blue-green and red colours depending on the type of illumination present. This colour change is known as the alexandrite-effect and is due to the presence of chromium in the chrysoberyl structure. The use of alexandrites in laser technology has required crystals of high optical quality, and those grown from melt or flux techniques are preferred to hydrothermally grown alexandrites. ESR has been used extensively to document the spectra of natural and synthetic alexandrites (Barry & Troup 1969; Troup & Hutton 1983). The gemmological properties of hydrothermally grown synthetic alexandrites were reported by Trossarelli (1986), and they are essentially identified on the basis of characteristic inclusions described therein.

Commercially available synthetic alexandrites are produced by flux or such melt methods as the Czochralski pulled and float-zone techniques (Nassau 1987). Once again they are differentiated from natural alexandrites primarily on the basis of inclusions (Gubelin and Koivula 1986). In the absence of such distinguishing inclusions, FTIR spectroscopy has been shown to be an effective technique for their

identification (Leung et al. 1983; Stockton and Kane 1988).The infrared spectra in the range of 2000-4200 cm^{-1} of natural and synthetic alexandrites showed significant differences. In particular, natural alexandrites displayed characteristic absorption features centred at about 2160, 2403, 4045, and 4150 cm^{-1}, which were not found in any of the synthetics. Furthermore, XRF-EDS investigations of some synthetic alexandrites studied by Stern and Hanni (1982), revealed presence of Mo which is used in the flux-growth process.

IMITATIONS

So far this brief literature review has covered only man made single crystals. The synthesis of non-single crystals such as lapis lazuli, opal, jadeite and turquoise has been hindered in some cases by technical difficulties which were not faced in the single crystal production techniques. By definition, true synthetics are those with natural counter parts, while imitations are man-made simulations of natural or synthetic stones, mimicking them only in appearance. As summarized in table 2-6, investigation is required at five different levels of magnification, in order to classify nonsingle crystals as synthetic or imitation. It must be noted that this table can equally apply for man-made single

crystals. According to Nassau (1976), synthetics can only vary from naturals at the microscopic level of examination (i.e., with respect to their inclusions). Variation at any other level of investigation would define an imitation gem.

Pierre Gilson of Switzerland, has been the major producer of most non-single crystals such as opal, lapis, turquoise etc.. The nature of the structure and optical effects in opal were explained by Jones et al., (1964) and Sanders (1964), respectively. Approximately ten years later Gilson had made black and white "Gilson-created Opals" available to the gem trade (Jobbins et al., 1976). The investigation at the five different levels of magnification of several opals made by Gilson revealed that they were in fact opal imitations rather than true synthetics (Schmetzer 1984). A more obvious imitation of opal is the so called Slocum Stone produced by John Slocum of Michigan, U.S.A.; essentially a silicate glass consisting of Ca, Mg, K and Al (Dunn 1977b).

Similarly, Gilson-created lapis lazuli does not deserve the label of a synthetic, as is claimed by the manufacturer. Obvious differences in physical properties such as lower hardness and density, as well as the fact that its predominant constituent is a hydrous zinc phosphate, can be used to identify Gilson's lapis lazuli imitation (Schmetzer 1985).

The X-ray powder pattern of Gilson's synthetic turquoise has been observed to be essentially the same as that of natural turquoise, with additional lines due to presence of crystalline phases such as berlinite. This product is considered to be the only true synthetic amongst such turquoise simulants as paraffin and plastic impregnated gibbsite or dyed magnesite, dolomite and calcite (Lind et al., 1983). FTIR has also been used to distinguish between natural turquoise and its imitations. The spectra obtained with this technique can also be used to differentiate between Gilson's synthetic turquoise and the naturally occurring minerals (Arnould and Poirot 1975; Rossman 1981).

Apart from these non-single crystal materials, glass, ceramics and plastics are in the next group of products that are intended to imitate natural gems. Glasses are silica based with the two common types being potash-, soda- and lime- containing crown glasses, and lead oxide bearing flint glasses. Molten glass is usually pressed into molds resulting in rounded edges and concave facets. Some common trade names for these glass imitations are strass, paste, rhinestone, lead crystal etc., but today these terms are used generically and interchangeably.

These glasses are easily identified on the basis of refractive index, density, hardness and inclusions. There are also some special glasses that show cat's eye effect and

others such as imitation ruby and sapphire that exhibit asterism. Other oddities include the so called goldstones which contain precipitates of copper crystals intended to imitate 'sunstone' (a variety of oligoclase), and a whole series of translucent and semi-opaque glasses. Needless to say, these imitations are also very easily identified by standard gemmological equipment and gem testing techniques as outlined by Webster (1983).

Ceramics are composed of fine-grained clays that are heated to produce polycrystalline solids which are intended to imitate gemstones. They are not faceted or polished but rather molded and glazed with a glassy coating. A well known example of this is the Egyptian faience which consists of a ceramic core covered with colourful glaze (Nassau 1980).

Plastic is a general term used for a variety of artificially produced materials and also one of the least expensive gem imitations. The rigid types of plastics include opaque, translucent and transparent products that are easily coloured by organic dyes or powdered pigments. Cellulose was one of the earliest known plastics and it is now largely replaced by synthetic resin plastics such as phenol formaldehyde (i.e., bakelite), methyl-methacrylate (i.e., plexiglass and lucite) and polyestyrene resins (i.e., lustrex and victron). Typically they have low hardness (moh 1-3), density (1.05-1.55 g/cc) and refractive indices (1.3-

1.6). Chemical tests with various reagents are used to confirm the presence of characteristic groups, for the purposes of distinguishing between the different plastics (Hurlbut and Switzer 1979; Webster 1983).

COMPOSITE GEMSTONES

The practice of assembling two or three smaller stones into one large composite dates back to the Roman times. Perhaps the main objective behind such a practice has been not only to produce a larger stone, but also to impart a better colour and appearance to stones of inferior colour and clarity. This has usually been achieved with a suitably coloured cement layer. The terms doublets and triplets are used to refer to composite stones made of 2 or 3 pieces respectively. There are many different types of composite stones and some of the most commonly encountered types are shown in figure 2-1.

Composite stones are easily detected when unset through careful handlens examination of the contact between the crown and the pavilion facets of the stone. In the case of doublets made of crown and pavilion parts of different

composition, immersion in methylene iodide will reveal the relief differences. Of course, in such doublets the refractive index reading will vary for the crown and pavilion as well. The join in the case of garnet-topped doublets (Figure 2-1,e) is achieved by fusing a thin piece of garnet (usually almandine) onto coloured glass, where the colour of the glass determines the overall colour of the intended composite stone. Microscope examination of such doublets usually reveals a series of bubbles concentrated in the original plane of separation. Further, if the stone is unset and placed table down on a white sheet of paper, the garnet top produces a red ring on the paper (Webster 1983).

TREATED GEMSTONES

Enhancement techniques are used to change or improve the colour and/or appearance, as well as some other physical properties of gem material. The history of gemstone treatment dating back to written accounts of Pliny has been reviewed by Nassau (1984). Many of the techniques such as foilbacking, oiling and dyeing are still in use today. Modern treatment processes are divided into three categories: impregnation and dyeing, heat, and irradiation.

Gem materials that are naturally porous or have fractures that allow penetration of variously coloured dyes and impregnating agents such as oils, paraffin wax, sodium silicate and plastic. Impregnating agents will intensify colour by preventing the scatter of light from porous materials and they can also contain dyes. Inorganic dyes are preferred over dyes of organic origin since the colour imparted by the latter has a tendency to fade. Oiling of sapphire, ruby and emerald with suitable oils is a well known fact of the trade, where the presence of such oils will fill fractures, making them less apparent (e.g., Ringsrund 1983). The detection of these types of treatment can in some cases be a difficult task, especially when "trade secrets" are not precisely known. In many instances, detection of treatment remains a highly visual process. Liddicoat (1981) has summarised a series of ancillary tests that may be applied in certain cases (e.g., dyed lapis may be detected by testing for colour fastness with acetone).

Heat treatment under oxidizing or reducing conditions can enhance or change the colour of gem material. This type of treatment can not only affect the colour, but also the inclusions and even the presence or absence of asterism. For example, the technical aspects of heat treatment of ruby and sapphire of natural or synthetic origin, for removing asterism or silk (undesirable rutile needles), enhancing the colour, and even altering characteristic inclusions, has

been reported by Nassau (1981). The procedure for identifying such treatments has been discussed by Crowningshield and Nassau (1981).

Apart from ruby and sapphire, quartz, beryl, topaz, zircon, tourmaline, and tanzanite are all also commonly heat treated. The resulting colour after heat treatment may in some cases like blue zircon, not be matched by any naturally occurring colour of that species. Alternatively, heat treatment can duplicate or complete natural annealing processes which are associated with crystal growth.

The last method used to alter the colour of gem material is irradiation with gamma or X-rays, or bombardment with energetic particles such as electrons, neutrons, protons and deuterons; and in the case of diamonds by exposure to radium salts. While gamma and X-rays do not induce radioactivity, the particles have this potential. Those particles with sufficient energy can change some of the trace element isotopes, thereby inducing radioactivity. The change in colour is primarily caused by presence of colour-centres, although in some cases they are not involved (e.g., beryl). A large variation is possible considering that irradiation can create those colour-centres in colourless material, can intensify those already existing, can restore those which have been bleached by heat or light, and can create new colour-centres which are not naturally occurring. Thus

irradiation-induced colour change may be stable or fade with exposure to light. The uniformity of colouration is poor for irradiation induced by X-rays and positive particles (i.e., protons and deuterons), while good results may be obtained with gamma rays, neutrons and electrons (Nassau 1984). This aspect of colouration has been used for detecting some irradiation-treated gemstones. However, the most reliable means for identifying these treated stones has been through application of spectroscopic and microscopic techniques. A few examples of such studies are Scarratt (1982) for diamonds; Schmetzer et al., (1983) for yellow and orange sapphires; Nassau and Prescott (1975) for topaz; and Schmetzer (1989) for citrines and prasiolites.

It appears as though the detection of various treatments requires a different approach in each gemstone. The most comprehensive compilation of treatment histories of common gem material may be found in Nassau (1984, p.91-174), together with a compilation of references dealing with their detection in each case.

TYPES OF GEMMOLOGICAL DATA : A SUMMARY

With the exception of organic gems, most gem materials are naturally occurring minerals with the attributes of beauty, durability and rarity. These gem minerals are easily

identified through determination of standard gemmological properties. The advent of gem-quality synthetics has necessitated the application of modern analytical techniques. These include XRF, EMPA, SEM, OES, AAS, NAA, PIXE, NMR and ESR. Furthermore, for gem material containing transition metal elements, UV-VIS-NIR spectroscopy has proved effective for distinguishing between natural and synthetic gems. Table 2-7 is a summary of techniques which have been used to characterise the most commonly encountered gem quality synthetics. These analytical techniques have in most cases been supplemented with detailed microscopic investigation of inclusions. This indispensable feature has proved to have great diagnostic value in addition to offering a rapid and convenient method for separating naturals from synthetics.

The techniques summarised in Table 2-7, have been equally important in the identification of non-single crystal imitations which include many of Gilson's products. More obvious imitations of gems are glass, ceramics and plastics, whose optical and physical properties are sufficiently different for more sophisticated testing methods to be unnecessary. In the case of natural, cultured and imitation pearls, X-radiography is the most widely used method for their identification.

Many different types of composite gems are encountered in the trade and their identification is based on methods such as immersion, fluorescence or microscopic investigation, which are intended to reveal the presence of a separation plane between the crown and pavilion of the faceted gem.

The treatment of gemstones was also included in this section due to the bearing that it can have on the optical and physical properties and more importantly on the value of the gem. The detection of various treatment processes is not unlike detective work, since it is difficult to choose a method sensitive to the problem where evidence is scarce. Microscopic investigation and absorption spectroscopy, together with the full range of gemmological tests are usually applied with varying degrees of success.

DISCUSSION

The purpose of this literature review has been to show the diversity of gem data associated with various gem materials. For computer storage and retrieval, the nature of data becomes an important consideration. Data can generally be regarded as being quantitative or qualitative. Quantitative data involve numerical measurements with minima, maxima, and averages. Of course, it is possible to assign and store

numerical values for qualitative data, where numbers can correspond to different divisions. In this case, minima, maxima, and averages are meaningless. Thus, words can be handled by the computer as readily as numbers. More importantly, computers can select, extract, sort, compare and integrate this data. Given these capabilities, the advantages of a computerised gem data base are apparent. For the GemIdent data base, the objective has been to apply these capabilities to various types of gem data.

Quantitative gem data consists of refractive index, birefringence, dispersion, density, hardness, cell parameters, elemental weight percentage, and absorption spectra. Qualitative gem data includes: symmetry, optical character, optic sign, diaphanaeity, pleochroic and fluorescent colour, overall "body colour" and inclusions. In a broad sense, all of these collectively represent the most widely used types of data involved in the identification of various gem material. Ideally one would like to accommodate all gem material and their associated data into one gem data base, however there are some problems with this approach which will be outlined below.

synthetics

The current thrust in chemical and spectral documentation of gem material has employed many different modern instrumental techniques. This has clearly been a reflection of the need for unequivocal identification of gem minerals, and their separation from synthetics. The results of such studies are not always published in detail, in fear of highlighting necessary changes for manufacturers who hope to close the gap between naturals and synthetics. In particular, where elemental abundances have been used for distinction, it is not clear whether apparent discrepancies in the literature, are a reflection of real chemical differences arising from different generations of synthetics or, alternatively due to errors associated with the detection techniques used. Moreover, while the analytical techniques exist for obtaining fully quantitative chemical analyses, the approach may be unacceptably destructive in nature (e.g., NAA in emeralds, or OES, AAS). Even in studies where techniques used can give fully quantitative data, there does not seem to be a complete consensus on the indicator elements (e.g., PIXE versus NAA study of rubies or emeralds).

The use of elemental abundances is an approach which has not proved effective in all instances. For this reason, absorption spectroscopy has become more important in recent years, and has enabled more accurate determination of

absorption features in UV-VIS-NIR. The problem with spectrophotometric measurements of absorption features is that the data is commonly analysed and interpreted in graphical form, where spectral differences are obvious. Frequently, the conclusions together with small graphical representation rather than the raw numerical data, are published. For complete computer processing and analysis, detailed spectral data are necessary and the recording of approximate spectral peak positions is inadequate and ineffective in any gem data base. What is required is adequate programming for processing of the complete range of absorption spectroscopic techniques available, with sophisticated implementation of spectral peak search and fit algorithms.

The contributions of detailed chemical and spectral data have been valuable to the distinction of some synthetics and naturals, but they also represent two approaches outside the realm of practicing gemmologists who are unable to conduct routine chemical analyses and are usually only equipped with hand spectroscopes. Fortunately, inclusions remain as indispensable marks inherent to the crystal growing conditions and observable with microscopes. However, inclusion data suffer from the lack of a common standard language, and their recognition is a highly visual process. Lack of a standard language for describing inclusions prevents complete usage of the selection, comparison and

integration capabilities of the computer. Nevertheless, it is such an important and essential diagnostic feature of almost all natural and synthetic gems, that where possible it must be included in any gem data base, even as non-searchable or retrievable data. Previously observed inclusion microphotographs, rather than the description of pictures are used in gem identification. Thus, ideally a computerised data bank of all observed inclusions is required. Presently, a comprehensive collection of inclusions exists in book format (Gubelin and Koivula 1986).

Given the constraints which apply to chemical, spectral and inclusion data, and their relative importance in distinction of gem minerals from synthetics, it was decided that synthetics would be excluded from GemIdent. The requirements for their incorporation in the GemIdent data base, would involve extensive programming for dealing with the entire range of spectroscopic techniques and data, as well as access to raw and unpublished spectral and chemical data. This still would not solve questions regarding different generations of synthetics with real chemical differences. Perhaps, if the manufactures of synthetics were more cooperative, documentation of data would become a more feasible task. This is highly unlikely. Nevertheless, the GemIdent data base can still be used effectively by researchers involved in synthetic investigations, since natural variations in optical, physical and chemical data of

gem minerals can be accessed and in turn manually compared to their results.

A possible long term solution for the accommodation of synthetics into a gemmological data base can involve the concept of linked data files (Robinson 1972). Linked data files can be viewed as data banks focusing and documenting one or two aspects of a particular problem. For example, a specialised data bank is currently under development by researchers at the Gemological Institute of American (GIA), containing detailed FTIR diamond spectra. It is used primarily in comparison of variously coloured diamonds of natural and synthetic origin. Sophisticated spectral processing and analysis programs are being implemented for comparison of spectra (personal communications with Dr. Shigley, 1989). Of course the compatibility of such linked data files with an accepted data base management program is essential for this idea to take hold.

imitations

Most of the quantitative gemmological properties of glass, ceramics and plastics can be easily accommodated in a data base. However, important diagnostic inclusions, together with curved facets and their general appearance cannot be effectively represented in a data base other than including

them under nonsearchable inclusion and miscellaneous remarks fields.

The distinction of different plastics is based on a series of chemical tests which reveal the presence of various characteristic groups. In the case of non-single crystalline products of Gilson, namely opal and lapis, they remain as the most effective imitations and have been mistakenly labelled as synthetic. Gilson opals resemble naturally occurring opals chemically and physically except that at the atomic level, electron microscope photographs reveal columnar regions not found in natural opals. They are also said to have a "lizard skin pattern" under high magnification.

While the incorporation of standard gemmological properties for imitations does not pose any particular problem it is insufficient for their complete characterisation. This is particularly true in the case of the plastics and Gilson's products. The extensive programming required for computer fields which would be used for only a very small number of gem materials (< 3%), has not been considered worthwhile. Thus imitations have not been included in the GemIdent data base.

composite gemstones

Identification of composite stones is achieved primarily through visual examination of the contact between the crown and pavillion facets. Other methods of identification involve immersion and fluorescence which are geared towards revealing the presence of a separation plane. None of these factors can be effectively included in a data base since they involve observations that are not easily quantifiable. The problem is also compounded by the fact that there are endless numbers of variations for composite stones. Today, composite stones are being largely replaced by plastics and synthetics. Composite stones have not been included in the GemIdent data base.

treated gemstones

The bearing that various treatments can have on properties such as colour, inclusions and value, makes their detection a prime concern. In the book "Gemstone Enhancement" (Nassau 1984, p.80), the state of treatment detection was summarised:

> "....even if a reader were to study carefully the standard texts such as Anderson's "Gem Testing" and Liddicoat's "Handbook of Gem Identification", backed by Webster's "Gems", and the author's "Gems Made by Man", this would still be insufficient. What is required is that ultimate of gemological instruments, the experienced eye, with the informed mind to direct the investigation."

The problem of gemstone treatment is compounded by the fact that the same treatment in different gems in many cases requires a new approach for its detection. This kind of variability is difficult to accommodate in a data base, where extensive programming is required for dealing with criteria that only apply to a few cases. Absorption spectroscopy coupled with microscopic investigation remain the two dominant approaches for the detection of treatment. Perhaps once again, the concept of linked data files can be used for representing treated stones in a gemmological data base. For example, the microscopic and spectroscopic study of the various treatments used for yellow and green quartz (Schmetzer 1989), is well suited for this purpose. Treated gemstones are not included in the GemIdent data base.

gem minerals

The majority of gems are gem minerals, and they have been incorporated into the GemIdent data base to the fullest extent. It was decided that all minerals that were considered in standard gemmological texts (e.g., Webster 1983; Liddicoat 1981) and especially the Color Encyclopedia of Gemstones (Arem 1987) were to be included in Gemident. In addition, any gem mineral available in the gemmological literature which had not been previously considered in the above references, was also included in the data base.

Three criteria were used in selecting the type of gem data to be incorporated. First and foremost, was the consideration of the diagnostic power of a given property with respect to gem identification. The next two criteria encompassed the universality and availability of a given gemmological property. Thus, properties determined by standard gemmological equipment were considered to be universally applicable, although not necessarily available. These properties include: optical character and sign, refractive indices, birefringence, dispersion, density, hardness, pleochroic and fluorescent colour, absorption spectra, and inclusions. In addition, the contribution of the overall 'body colour' of gems to their beauty, value, and properties, colour was considered to be an essential piece of data. From the outset, a data base consisting of a compilation of chemical data on gemstones was envisaged. GemIdent is the first gemmological data base which enables identification of gem minerals based on any combination of standard physical and optical properties, and most importantly, composition. For the sake of completeness, the symmetry, unit cell dimensions and angles, occurrence, and geographic locality of gem minerals together with the source reference of data, have also been included in the data base.

The structure of the GemIdent data base, the data base management program, and many of the types of data discussed

above, are identical to the MinIdent data base (Smith and Leibovitz 1986). MinIdent is a data base for minerals and a program for their identification. It contains physical, optical, and chemical data for over 4600 minerals. More details of the features available in MinIdent and GemIdent are included in the following chapter. Since GemIdent represents the first undertaking of its kind in gemmology, a more thorough examination of the peculiarities of the selected types of data noted above, is also presented in the following chapter.

Table 2-1: The name and abbreviations of techniques which have been used for the purposes of gem identification.

Standard Acronym	Technique	Reference
EMPA-EDS	Electron Microprobe Analyzer - Energy Dispersive Spectrometry	Dunn 1977a Stockton 1986
EMPA-WDS	Electron Microprobe Analyzer - Wavelength Dispersive Spectrometry	
XRF-EDS	X-ray Fluorescence Energy Dispersive Spectrometry	Stern & Hanni 1986
SEM-EDS	Scanning Electron Microscopy - Energy Dispersive Spectrometry	Stockton & Mason 1981
NAA	Neutron Activation Analysis	Henn & Schrader 1985
PIXE	Proton Induced X-ray Emission Spectroscopy	Tang et al. 1988, 1989

Table 2-2: Classification of commercially available gem-quality flux grown synthetic rubies based on the presence or absence of various types of seeds (modified after Schmetzer 1986b).

Group I	Group II	Group III	Group IV
Chatham	Chatham	Chatham	Chatham
Knishka	Knishka	Knishka	Knishka
-	Lechleitner	-	Lechleitner
-	-	-	Shinna
Inamori	-	-	-
Gilson	-	-	-
Kashan	-	-	-

Group I : Samples without seeds or with seeds produced by the same manufacturer.
Group II : Samples with natural seeds.
Group III : Samples with Verneuil seeds and thick synthetic overgrowth.
Group IV : Samples with Verneuil seeds and thin synthetic overgrowths, or without synthetic overgrowths.

Table 2-3: Average concentrations (in wt% relative to Al_2O_3) of relavent elements in 160 natural and synthetic rubies (after Tang et al., 1989)

ORIGIN	QUANTITY	K	Ca	Ti	V	Cr	Fe
NATURAL							
Afghanistan	1	0.018	0.063	0.004	0.010	0.490	0.109
Burma	40	0.010(010)	0.030(022)	0.021(032)	0.046(035)	0.439(314)	0.098(122)
India(loc1)	28	0.009(006)	0.033(024)	0.013(035)	0.011(005)	0.359(084)	0.182(065)
India(loc2)	10	0.006(004)	0.036(012)	0.200(042)	0.009(006)	0.870(213)	0.187(083)
Kenya	10	0.053(047)	0.069(091)	0.026(013)	0.031(012)	0.476(051)	0.049(069)
Sri Lanka	5	0.027(028)	0.044(030)	0.046(032)	0.019(022)	0.148(029)	0.545(459)
Thailand	39	0.006(006)	0.013(011)	0.019(011)	0.002(022)	0.314(111)	0.413(111)
SYNTHETIC							
Chatham	7	- *	0.008(004)	0.004(002)	-	0.528(087)	0.006(003)
Inamori	2	-	0.007(002)	-	-	0.303(003)	-
Kashan	6	0.012(010)	0.030(023)	0.034(016)	-	0.163(075)	0.031(019)
Knishka	1	-	0.011	0.005	-	0.247	0.159
Ramaura	5	0.008(006)	0.010(008)	0.002(001)	-	0.329(286)	0.037(046)
Seiko	1	-	0.005	0.002	-	0.386	0.006
Unknown	5	-	0.006(006)	0.007(001)	-	0.179(013)	0.004(004)

* below detection limit.

Table 2-4 has been removed due to unavailability of copyright permission.

For partial chemical analyses of natural and synthetic emeralds see Stockton (1984)

Table 2-5 has been removed due to unavailability of copyright permission.

For partial chemical analyses of Lennix, Biron and Russian Fluxes see the following references:
Hanni & Tschuclin (1983) Gubelin (1987a,1987,1985)
Kane & Liddicoat (1985) Koivula & Keller (1985)

Table 2-6: Observation at different levels of magnification for nonsingle crystal materials (after Nassau 1980)

Level	Approximate Size Range	Examination Techniques	Properties Observed	Congruency
1	Atomic Level, 0.1 nm	Elemental analysis, optical spectroscopy	Chemical composition valence states, impurity sites, colour centres	Yes
2	Up to 0.01 μm	X-ray diffraction	Crystal structure	Yes
3	0.1 to 1 μm	Electron microscope	Diffraction structure, etc.	Yes
4	1 μm to 1mm	Optical microscope, magnifying glass	Grain structure, inclusions, matrix, etc.	No
5	1mm to overall	Naked eye	Visible appearance	Yes

* The word "congruency" is used to describe the necessity for near complete agreement at a given level of examination of the synthetic with the natural material. In the absence of the necessary congruencies, the material may only be designated "artificial" or "imitation".

Table 2-7: Summary of techniques used to distinguish between gems of natural and synthetic origin.

Rubies	Verneuil	Microscopy	Gubelin & Koivula 1986
		ESR	Smith 1986
			Hutton & Troup 1988
	Flux	XRF EMPA	Schmetzer & Bank 1988
		XRD AAS	Schmetzer 1987
		PIXE	Tang et al., 1989
		NAA	Henn & Schrader 1985
Emeralds	Hydrothermal	EMPA XRF	Stockton 1984
	and	NAA OES	Schrader 1983
	Flux	FTIR	Stockton 1987
		ESR	Troup & Hutton 1983
Diamonds	GE	FTIR	Shigley et al., 1987
	De Beers	Microscopy	Shigley et al., 1986
	Sumitomo	Fluorescence	Koivula & Fryer 1984
Quartz	Hydrothermal	IR-spectros.	Lind & Schmetzer 1983
	transport	Microscopy	Lind et al., 1985
			Crowningshield 1986
			Schmetzer 1989
Alexandrites		Microscopy	Trossarelli 1986
	Hydrothermal	ESR	Barry & Troup 1969
	Flux & melt	XRF	Troup & Hutton 1983
	techniques	FTIR	Stern & Hanni 1982
			Stockton & Kane 1988

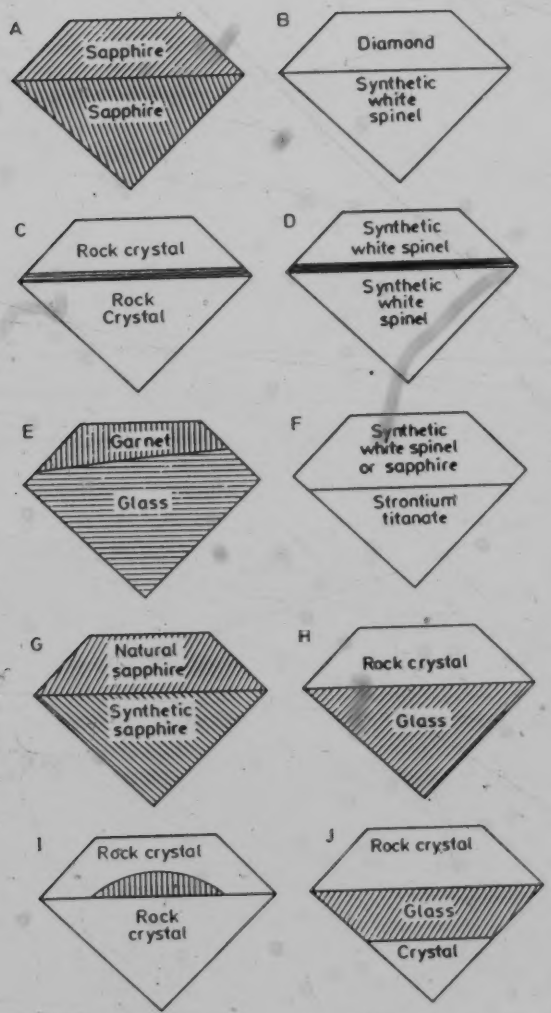


FIGURE 2-1: Types of composite stones: a) true doublet with top and base of genuine stone; b) diamond doublet; genuine diamond top with any inferior stone for base; c) quartz doublets: soude emerald; d) synthetic spinel doublet; e) garnet-topped doublet; f) doublet of two stones, usually made to simulate diamond; g) natural sapphire top and synthetic sapphire base; a doublet; h) quartz and glass doublet; i) liquid-filled hollow capped doublet; j) a triplet. (after Webster 1983).

CHAPTER 3:

THE GEMIDENT DATA BASE

INTRODUCTION

The GemIdent data base has been modelled after the MinIdent data base (Smith and Leibovitz 1986; Smith et al. 1989) because it already contained many of the features necessary for a gemmological data base and thus, relatively minor modifications had to be made to the data base management program. The software for both data bases has been developed by D.P. Leibovitz. Presently, it is a command driven, IBM compatible program, written in 25KLOC (kilo lines of code) of FORTRAN and 1KLOC of Microsoft FORTRAN C. The program occupies approximately 430 Kbytes of memory, and the data base uses a further 8.5 Mbytes. The GemIdent data base is literature based and being the first undertaking of its kind, it was essential to develop the syntax and semantics necessary for computerisation of parameters which were different from those available in MinIdent. This was accomplished with the collaboration of D.P. Leibovitz.

In this chapter the structure of the data base is described and it is followed by a discussion of all the properties that have been included in the data base. A section has been devoted to the description of the special facilities that are available in the data base, and methods for modification

of the data base have also been outlined. In addition, a brief review of the procedures involved in identification of gems using GemIdent has been included, with examples and applications to follow in the next chapter. The sources of error that may be present in the data base have also been discussed in this chapter. In a final section, a summary of the only other gem data base that is currently available is presented. Throughout the text, upper case lettering has been used to emphasise terminology that is specific to GemIdent.

THE STRUCTURE OF THE GEMIDENT DATA BASE

The structure of the GemIdent and MinIdent data bases are identical. Both data bases hold inter-related data in RECORDS, which consist of FIELDS. Gemmological and mineralogical properties are termed PARAMETERS and a different FIELD is used for every PARAMETER.

Gemmological data in the literature are considered to be of three different types. These are the MINERAL, SAMPLE, and GENERAL DATA. MINERAL DATA consists of those parameters which are constant from one sample of a gem mineral to the next. Examples are the formula, symmetry, optical character, and classification. On the other hand, much of the data in the literature pertains to particular samples of a gem mineral. This type of data is considered to be SAMPLE DATA

and a few examples of parameters belonging to this type of data are: refractive indices, composition, unit cell dimensions and angles and colour. Lastly, the literature data may be in the form of ranges of values, which were obtained from several different samples. These are referred to as GENERAL DATA, and they involve the same parameters as those used for SAMPLE DATA. These various types of data are contained in SAMPLE and GENERAL DATA DISPLAYS and each includes MINERAL DATA as well. An example of a SAMPLE DATA DISPLAY for tsavorite is shown in figure 3-1.

Yet another type of data is present in the MinIdent and GemIdent data bases, and they are referred to as COMPILED DATA. This type of data is generated by the program and used in the identification and match procedures. They represent calculated data of the maxima, minima, mean and in the case of compositions, standard deviations of the SAMPLE and GENERAL parameters. COMPILED DATA are contained in the COMPILED DATA DISPLAYS and an example of such a DISPLAY is shown in figure 3-2.

The relationship of MINERAL, SAMPLE, GENERAL, and COMPILED DATA, together with their associated parameters are presented in figure 3-3. The GemIdent parameters are discussed in the next section.

GEMIDENT PARAMETERS

There are a total of 28 parameters in the GemIdent data base. These parameters were selected on the basis of their potential as a determinative property, in addition to the universality of the property, and availability of data. Since no previously designated and widely accepted standard existed with respect to the recording of data pertaining to some of the chosen parameters, it was necessary to select suitable syntax, semantics, as well as allowable inputs which would lend themselves to computerisation. The description of parameters has been included in this section and a compilation of parameters and commands has also been prepared in the form of a User's Manual and presented in Appendix I.

The discussion begins with structural and optical properties, and continues with physical and chemical parameters, and finally ends with some miscellaneous parameters. Upper case lettering has been used throughout the text to emphasise the syntax as well as terminology which is specific to the GemIdent data base and program. For each parameter, the applicable types of data (i.e., SAMPLE/GENERAL/MINERAL DATA) are included in the headings under the term context. Examples of the applications of these parameters are included in the next chapter.

NAME
CONTEXT: MINERAL DATA; TABULATE PARAMETER

Problems in mineralogical nomenclature are resolved by the Commission of New Minerals and Mineral Names of the IMA (International Mineralogical Association). A comparable effort is necessary in gemmology. Nomenclature problems in gemmology stem from the use of trade names and misnomers, which in turn are partly due to the involvement of trade people with little knowledge of the scientific discipline. Frequently, two or more names are used for the same species/variety or alternatively, the same name is used for different species/varieties.

A list of disused gem names, misnomers, and trade names, with their corresponding correct names, obtained principally from Webster (1983), Zeitner (1976) and Hobbs (1982), has been incorporated into the GemIdent data base. Most of these are instances where two or more names are used to refer to the same species or variety. Some examples from this list are: water sapphires or lux sapphires for iolite, and copper emerald or emeraudine for dioptase. Trade names such as Kashan rubies or Leichleitner emeralds are accepted for synthetics. However, trade names have also been used for gems of natural origin. For example, "inca rose" is the trade name for rhodocrosite. The rationale behind the use of such trade names is perhaps to increase saleability.

Ultimately, it is the true nature, quality, beauty, rarity, size, and cut which determine a gem's value, not its name.

The problem of the use of the same name to refer to different species is best exemplified by the name jade. It is perhaps the least understood and most misused name of all. It appears that it has been prefixed and applied to many different compact and fine-grained minerals (e.g., swiss jade for dyed jasper; regal jade for aventurine quartz; and amazon jade for amazonite). To add to the confusion, there are many accepted and commonly used trade names for green jade. A few examples are: moss in the snow, kingfisher, yunan and maori stone (Hobbs 1982).

The name jade encompasses two distinctly different mineral groups, whose nomenclatures were revised. They are the amphiboles and pyroxenes (Leake 1978 and Morimoto 1988 respectively), specifically nephrite and jadeite. Nephrite was discredited by the IMA since it was a varietal name being used to refer to any member of the actinolite-tremolite series. The problem of nomenclature for the pyroxene jades is compounded by the fact that most jadeite-jades are intergrowths of jadeite with diopside and/or aegirine. Thus, the name jade encompasses these pyroxene intergrowths, as well as members of the actinolite-tremolite series. None of the recommendations made by the IMA, with respect to these two groups have been adopted in gemmology.

The science of gemmology can only benefit from precise and correct nomenclature. In the GemIdent data base, the IMA approved names for varieties, species, series, groups etc., are used. The names of all gem minerals that exist in the data base may be accessed through the MINERAL-RECORDS (MREC) command. Trade names and misnomers are included in the synonyms list, and may be accessed through the SYNONYMS-RECORDS (YREC) command. Request for data on any of the names in the synonymy list, will invoke a message regarding the correct name, with subsequent listing of data for that gem mineral. More details on names and classification problems are included in the discussion of the classification system used in GemIdent.

FORMULA
PROPORTION BASIS & PROPORTION SUM
CONTEXT: MINERAL DATA; TABULATE PARAMETER

All gem minerals in the data base have a chemical formula which has been obtained from Fleischer (1987). Where actual SAMPLE or GENERAL chemical compositions are not available, the FORMULA is used by the program to calculate chemical composition in terms of weight percentages.

The PROPORTION BASIS (PBASE) parameter is used to specify the elements on which the calculation of atomic proportions are to be based, and in the COMPILED DATA DISPLAYS those elements have an asterisks in the PBASE column. The sum of

the elements that form the basis of atomic proportions calculations must also be specified with the PROPORTION SUM (PSUM) parameter. The sum of the proportions of all the elements of a mineral is shown in the bottom of the ATOMIC PROPORTION columns of the SAMPLE and COMPILED DATA DISPLAYS.

SYMMETRY AND CELL PARAMETERS
SYMMETRY
CONTEXT: MINERAL/UNKNOWN DATA; TABULATE PARAMETER
CELL PARAMETERS
CONTEXT: SAMPLE/GENERAL/UNKNOWN DATA; TABULATE PARAMETER

The seven crystal systems reflecting the characteristic symmetries of the lattice types have been included in GemIdent. This parameter is contained in the SYMMETRY field, and allowable input consists of : monoclinic, triclinic, orthorhombic, hexagonal, trigonal, tetragonal, and cubic.

The unit cell dimensions and angles (A,B,C,and ALPHA, BETA, GAMMA parameters respectively) have also been included for the sake of completeness. X-ray diffraction techniques are the principal means for determining the values of these parameters. For such determinations and only where necessary, a small amount of powdered gem material may be obtained from the girdle area of faceted gems. This procedure is not widely practised since it is regarded as being essentially destructive.

Priority has been given to unit cell data determined from gem quality material. However, due to the destructive nature of X-ray powder procedures, only few such determinations exist in the literature. For this reason, the majority of data for unit cell parameters are from non-gem quality material. Where possible values of unit cell parameters determined from samples which were known to come from gem producing areas, have been included.

OPTICAL CHARACTER AND SIGN
CONTEXT: MINERAL DATA; TABULATE PARAMETER
REFRACTIVE INDICES, BIREFRINGENCE, DISPERSION
CONTEXT: SAMPLE/GENERAL/UNKNOWN DATA; TABULATE PARAMETER

In GemIdent, the optical indicatrices are referred to as the OPTICAL CHARACTER, and this parameter is set by the program once the symmetry is specified. Alternatively, in the event that only the optical character is known, the allowable inputs are : uniaxial, biaxial, and isotropic. The OPTIC SIGN parameter may be specified directly, or it will be automatically determined by the program, once the refractive indices have been specified.

The value of refractive indices are obtained with gem refractometers using monochromatic Na light (lambda=589 nm). They are entered via the NALPHA, NBETA, and NGAMMA parameters for biaxial, NOMEGA and NEPSILON for uniaxial, and N for isotropic crystals. The program ensures that the

parameters chosen for specifying the refractive indices are compatible with the optical character. The absolute value of the gem's birefringence is calculated by the program, once the refractive indices are specified. Alternatively, the value may be specified using the BIREFRINGENCE parameter.

In gemmology, the value of dispersion is taken as the difference between the refractive index measured in red (lambda=686.7 nm) and blue-violet (lambda=430.8 nm) light, which correspond to the B and G Fraunhofer lines of the solar spectrum. Unlike mineralogy, this numerical value of dispersion, rather than the convention of r>v and/or r<v is used in identification. The values may be found in the DISPERSION field.

A thorough review of procedures involved in determining the value of parameters discussed in this section, with such essential gem testing instruments as a gem refractometer and a polariscope, may be found in Hurlbut and Switzer (1979) and Webster (1983). In GemIdent all of these parameters may be used alone or in conjunction with one another for identification of an unidentified sample.

A special feature has also been incorporated for specifying orientationless refractive indices, since the correlation of the index of refraction corresponding to a particular shadow edge on the refractometer is usually not practised (e.g., in

biaxial minerals the nalpha parameter is usually the lower shadow edge). Uniaxial and biaxial gem stones producing two shadow edges on the refractometer are simply regarded as being doubly refractive, and the two values of the index of refraction are taken at the point where the shadow edges are farthest apart. To accommodate this widely practised method of refractometer reading, orientationless refractive indices may be specified for the unidentified sample via the REFRACTIVE INDICES parameter. This will result in a search for any combination of refractive indices in uniaxial and biaxial crystals, using either the MATCH or IDENTIFY procedures.

PLEOCHROISM
CONTEXT: SAMPLE/GENERAL/UNKNOWN DATA; TABULATE PARAMETER

Uniaxial and biaxial crystals may exhibit selective absorption which can differ with the vibration direction within the crystal. The resulting variation in colour is known as pleochroism. In GemIdent, the two pleochroic colours of uniaxial gems are contained in the DICHROIC COLOUR (OMEGA) and DICHROIC COLOUR (EPSILON) fields. Similarly, the PLEOCHROIC COLOUR (ALPHA), PLEOCHROIC COLOUR (BETA), and PLEOCHROIC COLOUR (GAMMA) fields contain biaxial pleochroic colours. For isotropic gem minerals the DICHROSCOPE COLOUR field has been used to specify the colour of gems as seen through the dichroscope

In the preliminary stages of data gathering it quickly became evident that the lack of a standard colour language not only affected the overall colour assigned to gems, but also the reporting of pleochroic and fluorescence colours. The literature is inundated with terms such as sky blue, coral red, straw yellow, cornflower blue, slightly violetish red etc.. In the light of the importance of pleochroism and fluorescence in gem identification, an attempt had to be made to accommodate this imprecise colour language. This problem is not uniquely related to the gemmological literature and, in fact, the same problem exists in the mineralogical recording of colour. Thus, the same colour terms as those used in MinIdent have been adopted in GemIdent (table 3-1). The majority of pleochroic data were obtained from Arem (1987), and the chosen allowable colour terms seemed satisfactory in most instances.

The procedure for observation of pleochroism with the aid of a polariscope or dichroscope has been outlined in Hurlbut and Switzer (1979) and Liddicoat (1981). One of the advantages of the dichroscope is in its design, which in turn allows simultaneous viewing of the pleochroic colours in uniaxial and biaxial gems. While it is possible to use the first principles of mineralogy to ascribe pleochroic colours to their respective vibration directions, it is common practice to report orientationless pleochroic

schemes. Thus, a special facility has been implemented in GemIdent which allows entry of orientationless pleochroic colours for unidentified samples. The applicable parameters are PLEOCHROIC COLOUR or DICHROIC COLOUR. The colours can be searched with the MATCH or IDENTIFY procedure, where any combination of the colours entered will be selected by the program, and presented as possibilities.

TRANSPARENCY
CONTEXT: SAMPLE/GENERAL/UNKNOWN DATA; TABULATE PARAMETER

The degree to which light is transmitted in a sample is contained in the TRANSPARENCY field of GemIdent. Allowable inputs are: transparent, semi-transparent, translucent, semi-translucent, and opaque. Most of the data for this parameter was obtained from Palache et al., (1944, 1951), Roberts et al., (1974) and Webster (1983). Needless to say, while the degree of transparency is important, it can be best used in conjunction with other properties for gem identification.

ABSORPTION SPECTRA
CONTEXT: SAMPLE/GENERAL/UNKNOWN DATA; TABULATE PARAMETER.

In gemmology, absorption spectroscopy encompasses the study of light which passes through or is reflected from the

gemstone. The colour of gems result from selective absorption of light, thus white light transmitted through or reflected from the gemstone, will reveal the missing wavelengths. Frequently, the spectrum is characteristic of minor and/or trace elements, which also impart the colour. It is important to note that not all gems exhibit diagnostic absorption spectra.

Two kinds of hand, otherwise known as direct-vision, spectroscopes are available for the observation of absorption spectra. These are the prism and diffraction-grating types of spectroscopes. The design and principles of these direct-vision spectroscopes are discussed in Webster (1983). The prism spectroscope is the most widely used type, and it can have a built in wavelength scale extending from 400-700 nm. The wavelength scale cannot produce accurate readings, given the limited divisions, which in turn results in inadequate resolution. Nevertheless, these approximate readings are considered to be satisfactory in gemmology. In fact, to the experienced eye, the visual arrangements of the bands and lines are sufficient for gem identification.

In the gemmological literature, the spectral data obtained with direct-vision spectroscopes, may be generalised to be presented in one of three ways: drawings resembling the photographic the image, written description of image, and approximate wavelength measurements. While the drawings may

be of some value in visual identification procedures, they were considered to be poor data and not suitable for the data base. The problem with written descriptions of spectra is incorrect specification of absorption lines and bands, where neither the beginning nor the end of absorption is indicated (e.g., broad band at 400 nm, or narrow band in the green). This kind of data was also considered to be inadequate for the data base. Where approximate wavelength measurements with correct recording for the beginning and end of broad bands, or centre for narrow bands were specified, they have been included in the data base. Spectral data may be found in the ABSORPTION SPECTRA field which can contain as many as 20 absorption lines and bands, stored in nanometres. The centres of the peaks are entered for narrow lines, and the beginning and end of absorption for broad bands are separated by a dash line (e.g., 427-490 nm).

A problem which applies to most published spectral data in the gemmological literature, is failure to record the gem's orientation with respect to the c crystallographic axis. Gems which exhibit pleochroism are likely to produce different spectra depending on their orientation. The difference in the spectra may be a change in the intensity or the appearance/disappearance of some line. However, in most cases this difference is not obvious when hand spectroscopes are used.

The majority of spectral data in the data base were obtained from Arem (1987). Unfortunately, the distinction between spectra obtained parallel or perpendicular to the c-axis is not made in this reference. It must be noted that the problem is related to difficulties which exist in obtaining spectra from faceted gems in any orientation.

Spectrophotometric measurements of absorption features have become increasingly available in the gemmological literature of the past decade. In most cases, data are presented in graphical form, together with the orientation of the gemstone. These data are preferred to those obtained with hand spectroscopes, since more accurate measurement of peak positions is possible. Provided the raw data were given, or if adequate readings from the graphs were possible, these have been included in the data base as well. The orientation of the spectra, where specified, is included in the REMARKS field. For those gems in which the parallel and perpendicular to c-axis spectra differ considerably (e.g., pyroxenes), only one orientation has been included, and a remark to that effect may be found in the SAMPLE and GENERAL REMARKS fields. Absorption data are best used in conjunction with other properties in gem identification.

COLORMASTER COLOUR
CONTEXT: SAMPLE/GENERAL/UNKNOWN DATA; TABULATE PARAMETER.

Colour is a major contributor to the beauty of gemstones, and forms the single most important clue in gem identification, so far as the eye is concerned. Many properties, such as the absorption spectra and elemental composition, may be related to the observed colour. Thus, a colour field was considered to be essential in GemIdent. The gemmological literature can be described as having a crude and imprecise colour language. Since GemIdent is literature based, there was no satisfactory way to accommodate the baseless variability of colour terms in the literature. It is the lack of a standard colour language in gemmology which prevents effective computer implementation of this parameter. Thus, priority was given to the implementation of a colour language which was designed specifically for gemstone colourimetry, and one that was well known and likely to be accepted as the standard.

There are two different approaches for defining and measuring colour. It must be emphasised that no matter which approach to colour measurement is taken, a 'standard observer' is necessary since colour is a subjective sensation. The two systems for specifying colour are (Chamberlin and Chamberlin 1980):

(1) Instrumental measurement of the relative amounts of each wavelength contributing to the overall body colour of objects. This instrumental measurement must then be correlated to a visualisable description of the colour sensation produced in the standard observer; and

(2) Visual comparison systems of colour description.

The instrumental measurement of colour involves the use of spectrophotometers and while the advantages of this approach are numerous, the sheer cost is prohibitive, in addition to requiring considerable expertise for obtaining reliable data.

Visual comparison systems of colour description involve the use of different colour standards in which the ordering of standards is based on scales of constant hue, saturation, and lightness. The Munsell Color System and the DIN (Deutsche Industrie Norm) system are well known examples. More details are discussed in Chamberlin and Chamberlin (1980), and Wyszechi and Stiles (1982).

Presently, there are five colour charts specifically designed for gemstone colour description, and they are essentially based on the Munsell system. They are the GIA Color Grading Chart, Gem Dialogue, Gem Color Manual, Gem Color Guide and the AGL (American Gemological Laboratories)

Color Scan. They are available at the commercial level only. Nelson (1986), Kremkow (1984), and Smith (1987) have included brief details of these systems. In general, these colour-appearance systems are only suitable for surface colours. Additionally, the chips are subject to fading, and they only embrace a portion of the colour gamut. Thus, they do not represent the best alternative for describing colour.

Visual comparison systems of colour description can also involve the use of instruments. The most commonly used visual instruments for colour description, are termed the visual tristimulus colourimeters. These instruments provide the capability for visual comparison of two objects or their optically manipulated images. One of the two objects is the sample, and the other is a calibrated reference standard. The only type of visual tristimulus colourimeter developed specifically for the gemstone industry is the GIA ColorMaster (Manson 1982; Nelson 1986), and it was chosen for specification of colour in GemIdent.

THE GIA COLORMASTER

The GIA ColorMaster and Colored Stone Grading System is designed for colour grading of naturally coloured and transparent faceted gemstones, that are routinely seen in the gemstone industry. In this system, colour is described in terms of its hue, tone (lightness) and saturation

(COLORMASTER HUE, COLORMASTER TONE, COLORMASTER SATURATION parameters). The ColorMaster is shown in figure 3-4. It uses the principles of the additive mixture of light for producing a colour field that is used to compare with a field containing the gemstone under consideration. In the colour field a colourless gemstone (spinel) is flooded with various mixtures of red, green and blue, where the amounts of each can be controlled until a colour match is achieved. The proportions of the 3 primary colours used may be taken from the digital readout.

The ColorMaster notation consists of the type of filter (A-G in figure 3-4) followed by the digital readout of the red, green and blue lights (e.g., D 68 36 22). These notations have corresponding verbal descriptions for the hue, tone and saturation. For example, D 68 36 22, corresponds to a medium dark moderately strong red-orange, or alternatively RO 6/4. These verbal descriptions communicate the colour in terms which can be visualised. The ColorMaster notations and their associated descriptive notations are presented in Appendix II. The 31 hues, and the different levels of tone and saturation used in this system, together with their usage in GemIdent are shown in table 3-2a to 3-2d.

This colour system also allows for the grading of additional colours, that may be present. The cause of additional colours (COLORMASTER CAUSE) are summarised in table 3-3. The, allowable input for this parameter are dominant and/or one of the causes listed in table 3-3. If additional colours have been noted, their strength must be specified with the COLORMASTER STRENGTH parameter (table 3-4). Thus the COLORMASTER-COLOUR (CMCOLOUR) parameter consists of the following: CMCAUSE, CMSTRENGTH, HUE TONE/SATURATION or CMNOTATION.

Presently, the only gems in the data base with ColorMaster colours are those belonging to the garnet-group, blue spinels, diaspore, and some peridots (personal communications with Stockton 1988). Additional colour notations were requested from the GIA, however none have been received to date (personal communications with Dr. Manson, 1989). For the purposes of identification of the unidentified sample, the compiled hues are used, since the tone and saturation can vary tremendously even with 2 gems that are cut from the same piece of rough.

FLUORESCENCE
CONTEXT: SAMPLE/GENERAL/UNKNOWN DATA; TABULATE PARAMETER

The fluorescent colours of gem minerals during exposure to long and short wave Ultraviolet radiation, are contained in the FLUORESCENCE LONG-WAVE-ULTRAVIOLET (FLW) and FLUORESCENCE SHORT-WAVE-ULTRAVIOLET (FSW) fields of GemIdent. Fluorescent data also suffers from the lack of a standard colour language. The allowable colour terms are the same as those used for specifying the pleochroic scheme. The majority of fluorescent data was obtained from Arem (1987), and only in a few cases was there incomplete overlap between the more flexible colour terminology used in the book, and those available in GemIdent. Fluorescent colours can be of diagnostic value; however, in gem identification they are best used in conjunction with other properties.

DENSITY AND HARDNESS
CONTEXT: SAMPLE/GENERAL/UNKNOWN DATA: TABULATE PARAMETER

The term density and specific gravity are used interchangably in GemIdent, since stored data for density are all in grams per cubic centimeters. The most important requirement for density measurement in gemmology, is a gem which is free from its setting. There are two approaches for the determination of density, they are known as the hydrostatic weighing method and the heavy liquid method. The

hydrostatic method is by far the most accurate and practical means of measurement for this parameter. Details on these two methods are outlined in Webster (1983).

The Mohs hardness scale is the universally accepted standard of hardness in mineralogy and gemmology. Hardness tests are carried out by means of hardness points or pencils, which are essentially mohs mineral fragments mounted on holders. The tests are carried out as close as possible to the girdle of the faceted gem, and never on the table or culet. The quality of polish on the facets can in many instances provide the best clue to the value of the hardness.

Density and hardness are frequently cited in the literature. Entry of values for unidentified samples is accomplished by the DENSITY and MOHS parameters. They are both of great value in gem identification, but best used in conjunction with other properties.

CHEMICAL COMPOSITION
CONTEXT: SAMPLE/GENERAL/UNKNOWN DATA; TABULATE PARAMETER

The current thrust in the use of various analytical techniques for chemical characterisation of gem material has largely been as a result of the need for the separation of synthetics from naturals. This topic was discussed in some length in the previous chapter. Nondestructive application

of different analytical techniques in gemmology represent new approaches in gem identification. The various techniques were also reviewed in the previous chapter. Chemical characterisation together with optical spectroscopy, have contributed to the understanding of the cause of colour in gem material, and the detection of some colour enhancement techniques. Moreover, it has enabled the application of precise nomenclature in the field of gemmology (e.g., tourmaline). GemIdent contains the first compilation of chemical data on gemstones. It is the first gemmological data base which can sort, compare, integrate and identify gems based on their elemental (or oxide) abundances.

Chemical documentation of gems and the study of their natural variations is a fairly new area in gemmology. It is first encountered in the literature of the late seventies, and has become more available since that date. Thus, not all gems have been analysed chemically, and for this reason it has been necessary to incorporate some analyses for non-gem quality minerals. Where possible, emphasis has been placed on obtaining analyses from transparent crystals and/or from localities which have been known to contain gem quality material.

Many gem minerals are rare and very few analytical data is available for them in the mineralogical or gemmological

literature. Thus, two types of compositional data are used by the GemIdent data base. They are the compositional data compiled from the literature and the calculated data which are generated by the program from the structural formula. Calculated data involve the determination of ranges of possible concentrations for chemical substitutions and the algorithms are the same as those used in MinIdent. The program also calculates the minima, maxima, mean and standard deviations for chemical data, where there are sufficient analyses (more than 5 analyses) to warrant this calculation. These values are contained in the COMPILED DATA DISPLAYS and are used in the MATCH or IDENTIFY procedures.

Chemical data for unidentified gems may be specified in weight percentages of oxides or elements. Alternatively, elemental abundances may be specified as being present in major, minor, or trace amounts (major=3-100 wt%, minor=0.1-5 wt%, and trace=0-1 wt%). More details on identification of samples using compositional data is included in the following section.

COLLECTION NUMBER
CONTEXT: SAMPLE DATA, TABULATE PARAMETER

Most published data are from samples belonging to various institutions and museums, and frequently the collection numbers are reported in the gemmological literature. In

GemIdent, the COLLECTION NUMBER field contains the institution/museum abbreviation followed by the sample number. These abbreviations are quite standard and those which have been included in the data base to date are listed in table 3-5.

The collection numbers may be accessed through the COLLECTION NUMBER RECORDS (CNRECORDS) command, which will result in the tabulation of the collection number, sample record number, and the name of the sample. Alternatively, they may be tabulated with the TABULATE command, or simply viewed in the SAMPLE DATA DISPLAY.

CUT AND CARAT WEIGHT
CONTEXT: SAMPLE DATA; TABULATE PARAMETER

Much of the SAMPLE DATA in the literature are from faceted samples, for which the type of cut, dimensions and carat weight are usually specified. Details of the cut and carat weight of samples are contained in the GemIdent fields: CUT-TYPE, CUT-LENGTH, CUT-WIDTH, CUT-DEPTH and CUT-WEIGHT. The CUT-TYPE parameter is used to specify the shape or design in which the gemstone is cut. The standard faceting arrangements which constitute the allowable inputs for this parameter are: rectangular cushion, square cushion, square

antique cushion, rectangular antique cushion, rectangular step cut, square step cut, heart, pear, marquise, oval, round, and mixed.

The dimensions of a faceted gem are contained in the CUT-LENGTH, CUT-WIDTH, CUT-DEPTH fields, and they are specified in millimeters. The CUT-WEIGHT parameter is used to specify the carat weight of samples.

It is not possible to MATCH or IDENTIFY gems in the data base on the basis of their cut and carat weight. Since most faceted gems with such data are also associated with a collection number, they may be located via the CNRECORDS command, or the TABULATE COMMAND.

All SAMPLE DATA DISPLAYS also contain essential fields necessary for full descriptions of a gemstone's cut, clarity, proportions, and finish. These fields are contained in a second page of the SAMPLE DATA DISPLAY (see figure 3-1). These fields have been modelled after the data sheets used for recording of such data at the GIA. They have been included in the data base with future developments in mind, and, at present, are empty fields due to lack of suitable data. Required data is only available for gems which belong to some teaching collections, or important gems in museum collections. These fields may also apply to gem appraisals.

Since the data base is presently completely literature based, these parameters will not be discussed further.

INCLUSIONS
CONTEXT: SAMPLE/GENERAL/UNKNOWN DATA; TABULATE PARAMETER

Inclusions are sometimes regarded as undesirable flaws affecting the clarity of faceted gems. However, not only may there be true beauty in the appearance and arrangement of inclusions, but also a wealth of information about their origin. These latter aspects of inclusions can be found in the " PhotoAtlas of Inclusions in Gemstones " (Gubelin and Koivula 1986), where hundreds of photomicrographs have been used to document the internal world of gemstones. It is the most comprehensive visual reference book on gemstone inclusions.

The advent of synthetic gems gave rise to gemmological microscopy, whereby inclusions were used to prove the origin of a gemstone. Gemmological microscopy has become the most important and convenient method of investigation of the origin of a gem, available to jeweller/gemmologist, requiring a stereo-microscope. Although two inclusions are rarely exactly alike, photomicrographs of previously documented inclusions are used for comparison and identification.

Inclusions can also be characteristic of a certain locality and species. Some gem deposits have geological circumstances which result in distinctive inclusions. Parisite crystals in emeralds, for example, are characteristically associated with the Muzo deposits in Colombia. On the other hand, certain inclusions can be characteristic of specific species. Thus, rows of "pearl-necklace"-like crystals of dolomite and hercynite, identify the host gem as spinel. Given all the above, there is still a considerable amount of variability with respect to the type of inclusions that may be present in species from different localities.

It is due to this variability perhaps, that inclusion data suffer from the lack of a standard language. After all, what better way to describe partially healed tension halos in peridot, than "lily pads". The term conjures immediate images of radially arranged droplets which can in turn be used in recognition of decrepitation halos. Of course, tension halos do not always resemble 'lily-pads' and, in fact, in aquamarines they are sometimes termed "snow stars", due to the white colour and their resemblance to stars. The literature is inundated with articles which outline inclusions in a very descriptive language. It is the variability in the descriptive language together with the numerous possibilities, that prevent effective computer comparison and integration for identification purposes.

Nevertheless, due to the importance of inclusions in gem identification, they have been incorporated in an INCLUSION field in GemIdent.

In general, reported inclusion data has been entered in the data base only where other physical, optical or chemical data were also available. SAMPLE and GENERAL inclusion data may be accessed through the DISPLAY or TABULATE commands. This field may also be string searched. Examples of this feature are included in the following chapter.

REMARKS
CONTEXT: SAMPLE/GENERAL/UNKNOWN DATA; TABULATE PARAMETER

The REMARKS field in GemIdent is reserved for any miscellaneous information which was available in the literature. This parameter has proved particularly useful for the inclusion of various information considered to have some relevance to gem identification, but which could not have been incorporated in other fields. In the case of compositional data, weight percentages of loss on ignition or total rare-earth contents are included in the REMARKS fields. Properties such as phosphorescence, thermoluminescence, piezoelectricity, and pyroelectricity, which can all be of importance to some gems, have also been

included in this field. It may also contain general comments about the rarity, colour and appearance of a gem.

The comments in this field may be string searched, where all the SAMPLE and GENERAL REMARKS will be searched for up to 20 characters. Examples of this feature are included in the following chapter.

OCCURRENCE AND LOCALITY
CONTEXT: SAMPLE/GENERAL/UNKNOWN DATA; TABULATE PARAMETER

Many of the famous gem occurrences and localities such as the metamorphosed limestones of upper Burma, known as the Mogok Stone Tract, are well known and documented in the literature (Keller 1983). At the same time, the specific locality and occurrence of a gem are perhaps, one of the first pieces of information that are lost. Gem dealers frequently, knowingly or unknowingly, assign incorrect localities to gems and therefore, all gem localities must be treated with caution.

In general, the physical and optical properties of gems do not differ enough to enable their association with specific localities. However, inclusions and composition can be indicators of provenance. For example, a trace element study of rubies conducted by Tang et al. (1988, 1989), associated Fe contents in the order of 4000 ppm with Sri Lankan or Thai

deposits. The recent compilation of inclusions in gemstones by Gubelin and Koivula (1986) emphasises the characteristic inclusions of gems from well known localities. Given the above, there is still a certain reluctance associated with the certification of locality by most gem testing laboratories.

The SAMPLE and GENERAL OCCURRENCE and LOCALITY may be string searched for words and/or characters which are up to twenty characters. There are many publications dealing with different gem localities. Where in addition to locality and occurrence, gemmological properties have been reported, these have been included in the data base. It must also be pointed out that due to the lack of sufficient data from many gem localities, it has sometimes been necessary to supplement the GemIdent data base with data from non-gem producing areas. Examples of string searches have been included in the following chapter.

SOURCE
CONTEXT: SAMPLE/GENERAL/UNKNOWN DATA; TABULATE PARAMETER

The SOURCE field in GemIdent contains the literature reference from which the SAMPLE and GENERAL data were obtained. The source reference consists of the abbreviated title, volume, and page for journals, and the author, year of publication, and the abbreviated title for books.

The most frequently used gemmological journals were: Journal of Gemmology, Gems and Gemology, Australian Gemmologist, and Zeitschrift der Deutschen Gemmologischen Gesellschaft. Due to the paucity of the University of Alberta's library holdings in the field of gemmology, many of the journals and related texts were obtained through interlibrary loans. The only available journal at the University of Alberta library is the Journal of Gemmology (holdings from 1970 to present). This Journal has been searched systematically for data. The abstracts in this Journal and those in the Mineralogical Abstracts, were the main leads to potential articles in other journals.

The most useful gemmological texts were Webster (1983) and Arem (1987). In fact, the entire "Color Encyclopedia of Gemstones" by Arem (1987), has been entered in the data base as GENERAL DATA (permission was obtained form Dr. Arem, personal communications, 1989).

Apart from the above gemmological references, mineralogical journals and texts were also used to fill the gaps in the data base. In particular, the American Mineralogist, Canadian Mineralogist, Mineralogical Magazine, and Neues Jahrbuch fur Mineralogie Abhandlungen, and Neues Jahrbuch fur Mineralogie Monatshefte. The most frequently referenced mineralogical texts were Dana (1911), Palache et al. (1944

and 1951), and all the volumes by Deer et al. (1962, 1963, 1978, 1982). Mineralogical references were used only where data was not known to be available in gemmological references. However, in many cases the mineralogical sources were found to contain data on specific gem-quality minerals. Where this was not specified, priority was given to data from transparent samples, and/or from localities where gem quality material are known to exist. Future developments of the GemIdent data base can include replacement of such data with newly-published data obtained from gem quality material.

The dual purpose commands of GENERAL RECORDS and SAMPLE RECORDS (discussed in the next section), can be used to list all the sources together with their associated RECORD NUMBERS. Alternatively, the TABULATE command may be used to list this parameter. In addition, this field may be string searched. Example are included in the following chapter.

SPECIAL FACILITIES

The special facilities which were available in the MinIdent data base have also been retained in GemIdent. They consist of the STATUS, HELP, RECORDS, SUBSETS, SYNONYMS, and CLASSIFICATION facilities. With the exception of the RECORDS facility, all of the other features are identical to those

available in MinIdent. Details of each of these are presented in this section.

STATUS

The STATUS command can be used to obtain the following information about the GemIdent data base: the number of MINERAL, SAMPLE, GENERAL and SYNONYM RECORDS; the number of UMCOMPILED RECORDS; and the number of SAMPLE, GENERAL, and COMPILED RECORDS that need to be displayed. The STATUS of the data base may be obtained by simply entering the term STATUS. The present STATUS of the GemIdent data base is as follows:

425 MINERAL, 1289 SAMPLE and 900 GENERAL RECORDS
759 SYNONYM RECORDS
447 SAMPLE RECORDS with COLLECTION-NUMBERS

Any modification of the data base with the ADD, EDIT, DELETE, or MOVE commands, necessitates reCOMPILing in order for the changes to take effect in the COMPILED DATA (see section on modifying the data base). This is an important factor, considering that all identifications are based on COMPILED DATA values. Thus the STATUS facility keeps a record of the number of minerals which need to be COMPILED. Once modifications are completed, the latest version of the RECORDS is DISPLAYed and copied to the printer. Hard copies

of the most recent SAMPLE, GENERAL, AND COMPILED MINERAL DISPLAYS are kept on file. A tally of modified RECORDS needing to be DISPLAYed is also given by the STATUS facility.

HELP

An online HELP facility containing details of all commands, procedures, and parameters is available in GemIdent. The GemIdent HELP file is presented as a Reference Manual in Appendix A. HELP messages for those parameters which were different from those available in MinIdent, or those which were implemented especially for GemIdent, were developed in collaboration with D.P Leibovitz. Information can be obtained by typing HELP followed by any applicable term. This will invoke a tabulation containing information on the definition, form (abbreviation), context, usage (syntax and semantics), units, examples and additional notes pertaining to the term. Upper case lettering in the form and syntax denote the minimum abbreviation that may be used. A list containing all the terms which can be explained in this way may be obtained by typing the term LIST (table 3-6).

RECORDS

There are various RECORD commands that are used primarily for accessing the RECORD NUMBERS. These are:

```
MINERAL     RECORD (MREC)
SAMPLE      RECORD (SREC)
GENERAL     RECORD (GREC)
SYNONYM     RECORD (YREC)
COLLECTION NUMBER RECORD (CNREC)
```

The MREC command may be used to obtain the names of gem minerals in the data base. It is particularly useful for accessing lists of gem names which begin with any string, a prefix or any letter of the alphabet. MREC tabulations also include the number of individual SAMPLES and GENERALS associated with a given gem mineral. The RECORD numbers of the SAMPLES and GENERALS may be obtained with the SREC and GREC commands respectively. The two latter commands are useful prior to the DISPLAY, SHOW, EDIT and DELETE commands, where the RECORD NUMBERS of particular SAMPLE or GENERALS are necessary. The YREC command can be used to obtain the SYNONYM RECORD NUMBERS in the data base. This record number is needed for modification or deletion of SYNONYMS only. The final RECORD facility available in GemIdent is CNREC command and it is used for obtaining the SAMPLE RECORD NUMBER that is associated with a given collection number. Typical

tabulations from the MREC, SREC, GREC, YREC and CNREC commands are shown in table 3-7.

Once the SAMPLE and/or GENERAL RECORD NUMBERS are obtained with the SREC and GREC commands, the DISPLAY command may be used to obtain entire RECORDS which contain further information. The TABULATE command may be used to list values of parameters from various SAMPLE and/or GENERAL RECORDS. This is particularly useful for comparison purposes and examples of this facility are included in the next chapter.

SUBSETS

The SUBSET facility in GemIdent is intended principally for the restriction of the data base to a select number of gem minerals. Table 3-8 outlines the procedure for the creation and use of SUBSETS. They are created by READing in a previously prepared list of gem minerals they are then SAVEd to a file. Once SUBSETS have been created, they may be LOADed for use at any time. SUBSETS may also be created by the TRANSFER command, where the most recently MATCHed or IDENTIFied minerals can be placed in a file, and LOADed when required.

The GIA has divided the most frequently encountered gems in the market place into two groups. They are referred to as Group A and B gems, and they have been created as SUBSETS for the GemIdent data base. The gem minerals contained in these groups are tabulated in table 3-9. Other SUBSETS can easily be created by following the directions in table 8.

The use of this feature in identification procedures can limit the search time considerably. Examples of applications of this facility are included in the next chapter.

SYNONYMS

A synonymy list in GemIdent includes commonly encountered misnomers, trade names, archaic names, and spelling variations. The majority of synonyms were obtained from Webster (1983), Zeitner (1976) and Hobbs (1982). There are 759 SYNONYM RECORDS and they may be accessed through the YRECORDS command. For example, all synonyms beginning with "orient" may be obtained by typing YREC ORIENT (table 3-10). For each synonym, the correct name, source reference and any related remarks have been included. A request for data on names contained in the synonyms list will invoke a message containing this information, with subsequent listing of the requested data for the correct name.

The addition, deletion and modification of synonyms involve the ADD/DELETE/EDIT SYNONYM (mineral) commands respectively. These have been discussed in the next section on modifications of the data base.

CLASSIFICATION SYSTEM

The structure of the GemIdent classification system is the same as the mineral classification system available in MinIdent. The lack of a universally accepted mineralogical classification scheme has been a hinderance in complete implementation of a classification scheme with defined levels. Terms such as class, group, family, species, variety etc., are commonly used without any limitation. For example, the spinel group or spinel family seem to have been used interchangeably in the literature. The spinel classification in general, represents a number of minerals with similar structures. However, terms such as group and family do not always imply structural similarity. The problem of different possible nomenclature levels is not equally complex for all gem minerals. Despite the lack of defined levels, the following hierarchical scheme of classification is used in both data bases:

```
TYPE
 CLASS
  FAMILY
   SUPER-GROUP
    GROUP
     SUB-GROUP
      SERIES
       END-MEMBERS
        SPECIES
         SUB-SPECIES
          POLYTYPES
           VARIETY
```

The fundamental division of the classification in both data bases is based on chemical composition and is referred to as TYPE. Thus silicates, carbonates, and oxides, are all examples of TYPES. The work of Hey (1962, 1963), Palache et al. (1944, 1951) and Ferraiolo (1982) have been used extensively for assigning TYPES to gem minerals.

The division of CLASS has been used mainly for the different divisions of silicates (e.g., nesosilicates, cyclosilicates etc.,). The GROUP and FAMILY designations used in the "Glossary of Mineral Species" (Fleischer 1987) were also used in GemIdent. The divisions of SPECIES and SERIES were exclusively reserved for those gem minerals with such status in that reference as well.

The garnet classification exemplifies some of the difficulties involved in the implementation of a

classification system. Stockton and Manson (1985) proposed a new classification for gem quality garnets taking into account the newly discovered East African garnets (i.e., tsavorite and malia), which did not fit the existing classifications. In practical gemmology, the colour, absorption bands, density, refractive indices and inclusions are used to place garnets in their correct categories (Anderson 1959). This is not entirely satisfactory, given the complexities of garnet chemistry. Thus, an examination of all gem quality garnets using chemical analyses as well as standard gemmological tests was undertaken and incorporated in the proposed classification, keeping in mind its application in practical gemmology (Stockton and Manson 1985).

The proposed eight categories of garnets based on chemical composition are: grossular, andradite, spessartine, almandine-spessartine, almandine, pyrope-almandine, pyrope, and pyrope-spessartine. Varietal names such as rhodolite, topazolite and demantoid, were also considered in this classification. However, all these categories have been given species status. For gemmological purposes a species was defined as "a naturally occurring inorganic substance that has a definite crystal structure and a fixed (natural or arbitrary) range of chemical composition within the compositional limits of its mineral group" (Stockton and Manson 1985, p.214)

This classification has been implemented in the GemIdent data base with the exception that the categories of almandine-spessartine, pyrope-almandine and pyrope-spessartine were classified under series rather than species, in order to stay consistent with the use of these divisions in the database. The garnet classification is shown in table 3-11.

The classification has been completed for as many gem minerals as possible. While the degree of completeness differs for each mineral, all gem minerals have at the very minimum been classified under a TYPE and SPECIES designation. The revised classifications of pyroxenes and amphiboles have been implemented to according to the scheme proposed by the IMA subcommittees on pyroxene and amphibole nomenclature (Morimoto 1988 and Leake 1978 respectively). The only exception is nephrite which has been classified as a species of the actinolite-tremolite series. This is consistent with the composition of gem-quality nephrites and the name is gemmologically significance and still used widely.

It should be noted that new gem minerals cannot be added to the data base unless they are classified. The procedure for

the specification of this classification is given table 3-12.

MODIFYING THE GEMIDENT DATA BASE

The GemIdent data base can be modified with any of the following commands:

```
ADD    — MINERAL/SAMPLE/GENERAL/SYNONYM (mineral)
EDIT     MINERAL/SAMPLE/GENERAL/SYNONYM (mineral)
DELETE   MINERAL/SAMPLE/GENERAL/SYNONYM (mineral)
MOVE     SAMPLE/GENERAL
MERGE    (mineral) (synonym)
BATCH    (file)
COMPILE
```

The ADD command may be used to add MINERAL, SAMPLE, GENERAL, or SYNONYM DATA to the data base. Addition of SAMPLE or GENERAL DATA to existing gem minerals is made via the ADD SAMPLE (mineral) or the ADD GENERAL (mineral) commands respectively. Alternatively, the ADD ANY (mineral) command may be used for simultaneous entry of SAMPLE and GENERAL DATA, provided the parameters for the GENERAL DATA are prefixed with "g.". Addition of new gem minerals is achieved with the ADD MINERAL (mineral) command. For the addition of a new mineral, the minimum data entry requirements are its formula and division within the classification scheme. Synonyms are added via the ADD SYNONYM (synonym) command.

SYNONYM DATA consists of the correct name, source of reference, and related remarks. In order for these types of modification to be stored in the data base, all ADD commands must be completed with the SAVE command. A summary of the ADD command is shown in table 3-14.

The EDIT command may be used for the correction of MINERAL, SAMPLE, GENERAL, or SYNONYM DATA contained in the various RECORDS. This command requires the SAMPLE and GENERAL RECORD NUMBERS (e.g. edit sample 435; edit general 299). The SREC and GREC commands may be used to obtain the desired RECORD NUMBERS for SAMPLE and GENERAL RECORDS. To EDIT MINERALS and SYNONYMS, their names rather than their RECORD NUMBERS are used, and the MREC and YREC commands apply (e.g., edit mineral euclase; edit synonym disthene). EDITing must always be completed with the SAVE command, at which point the edited version of the data is stored in the data base. Incorrect data may simply be replaced by correct data, through reassignment of that parameter. In the case of compositional weights, the entire chemical analysis must be nulled prior to reassignment.

The GemIdent program enters a user input loop when the ADD or EDIT commands are issued. Depending on the type of data that is being added or edited, this input mode is prefixed and designated by some form of the following prompt: "SAMPLE/GENERAL/MINERAL/SYNONYM input?". It is a prompt for

the user to input values for desired parameters. This loop is exited once the SAVE command is issued, and the "GemIdent command?" prompt reappears.

The deletion of SAMPLE, GENERAL, MINERAL, and SYNONYM RECORDS is accomplished via the DELETE command. The DELETE command is similar to the EDIT command in that it requires the SAMPLE and GENERAL RECORD NUMBERS for deletion of SAMPLES and GENERALS, and the name of the mineral and synonym for the deletion of the MINERALS and SYNONYMS (e.g., delete sample 78; delete mineral taprobanite; delete synonym emeraudine). The deletion of a MINERAL RECORD will automatically result in the deletion of all associated SAMPLE and GENERAL RECORDS, after a request for positive confirmation. Gem minerals that have been classified at the top of any hierarchy cannot be DELETEd, until all divisions beneath that TREE are DELETEd first. Thus, if mineral B is classified as a variety of mineral species A, species A cannot be DELETEd without having DELETEd variety B first.

The MOVE command can be used to move SAMPLE or GENERAL RECORDS from one mineral to another. This facility is of interest when a given data set has been redefined. Thus, incorrectly designated SAMPLE and/or GENERAL RECORDS may be reassigned to other minerals. In the event that all SAMPLE and GENERAL RECORDS are involved, the entire mineral may be renamed rather than deleted and reentered. This may be

achieved with the EDIT MINERAL (mineral) command, followed by the reassignment of the name of the mineral, provided the new name does not exist in the data base. If the new name already exits in the data base, then the two minerals need to be MERGED.

The MERGE command combines the SAMPLE and GENRAL RECORDS of the (synonyms) with that of a specified (mineral) (e.g., merge kyanite disthene). The MINERAL DATA of the (synonym) and (mineral) must be identical in order for this operation to take place. This command offers an alternative to MOVing all the SAMPLE and GENERAL RECORDS to the correct name and DELETing the incorrect MINERAL RECORD.

All the above types of modifications can be processed via the BATCH facility, where all additions, deletions, and modifications are entered in an ascii file, and subsequently BATCHed (e.g., batch gem1.doc). This facility offers a considerably faster method of modifying the data base and allows the user to inspect and reaccess data prior to processing. It also provides a useful record of the changes that were made and data that were added.

Following any of the types of modifications discussed above, the COMPILE command must be used. COMPILing involves the calculation of the mean, maxima, minima, and in the case of weight parameters, the standard deviations (only where the

number of records warrants it), of all numerical data for minerals in the data base. This GemIdent operation consist of three different commands. These are:

COMPILE UNCOMPILED ALL...compiles all modified minerals;
COMPILE UNCOMPILED.....compiles all modified divisions with less than 10 subdivisions; and
COMPILE (mineral).....compiles a specified mineral.

After many modifications have been made to the data base, the COMPILED UNCOMPILED ALL command is used in order for the modifications to be taken in to account in the COMPILED DATA. Alternatively, the COMPILE UNCOMPILED command may be used if there have been several modifications made to a recently COMPILED data base. COMPILE (mineral) command may be used after any modification of a given mineral. Compilation is essential considering that it is these types of data that are searched in the identification procedures.

GEM IDENTIFICATION

One of the primary functions of GemIdent is identification of gems. Unidentified gem minerals and their associated input data are referred to as UNKNOWNS and UNKNOWN DATA respectively. The mineral identification program, which is the same as that used in MinIdent, offers two procedures for identification. These are the MATCH and IDENTIFY procedures. In both cases the entire data base is searched, unless a SUBSET has been LOADed prior to selection of either command.

The TABULATE, DISPLAY, and SHOW commands are also discussed in this section.

The MATCH command results in a search for gem minerals that exactly match the UNKNOWN DATA. In order to consider all possibilities, input data are entered as ranges so as to allow for some latitude in the MATCH procedure. Gem minerals whose properties lie outside the range specified for the UNKNOWN, will be rejected in the MATCH process.

The IDENTIFY command is different from the MATCH command in that it selects the twenty most likely gem minerals based on the UNKNOWN DATA. In this procedure, demerit points are assigned for mismatches when one or more of the UNKNOWN parameters do not exactly match those in the data base. The demerit points are presented in terms of a TOTAL MATCHING (TM) INDEX. This calculation takes into account the degree of mismatch as well as the importance of the parameter that did not match. The IDENTIFY procedure results in the selection of the 20 most likely candidates with the highest TM values.

The TM index is a weighted combination of the following indices:

COMPOSITIONAL MATCHING (CM) INDEX;
OTHER PROPERTIES MATCH (OPM) INDEX; and
INFORMATION MATCH (IM) INDEX

Where compositional data are available, the TM index retains a bias towards the CM index, since the strength of GemIdent and MinIdent lies in the compositional data contained in each of the data bases. Therefore, the TM index can be primarily viewed as a weighted index between the CM and the OPM indices. The IM index on the other hand, is based on the proportion of UNKNOWN properties that matched with the available data in the data base. In effect, this index allos for the problem of missing data which may be due to gaps in the literature or in the data base itself. The significance of the IM index decreases as the data base becomes more complete. It should be noted that only the parameters entered for the UNKNOWN will be taken into account in the calculation of the above indices. For example, if compositional data were not available and UNKNOWN DATA consisted of optical data only, good IM and TM indices could still be obtained with the IDENTIFY procedure. These indices may be viewed via the TABULATE command.

If adequate margins of uncertainty are used in assigning values to various parameters, the MATCH procedure can effectively reduce the number of possibilities. The search may then be continued by employing the MATCH AND or the IDENTIFY AND commands. The AND in these latter commands signifies a logical AND, where only the previously MATCHed or IDENTIFied possibilities are considered. Thus UNKNOWN DATA may be MATCHed or IDENTIFied against the entire data

base and then these procedures may be repeated with the MATCH AND and IDENTIFY AND commands, in which the previously reduced number of possibilities are used in the search.

The UNKNOWN EDIT command can be used to assign narrower ranges or exact values, or additional data to the existing UNKNOWN DATA prior to the MATCH AND or IDENTIFY AND commands. EDITing of UNKNOWN DATA may also be used to give additional data.

The recommended procedure for the identification of gems using GemIdent is to MATCH the UNKNOWN DATA first in order to reduce the number of possibilities. Subsequently, the UNKNOWN EDIT command may be used to assign exact values to UNKNOWN parameters, add additional UNKNOWN DATA, or give narrower ranges for the already specified parameters. It should be noted that in the case of compositional data, the previous values must be nulled prior their reassignment, in all other cases new values will replace old values with reassignment. The revised UNKNOWN DATA may then be used in conjunction with the IDENTIFY AND command, in order to select the 20 most likely gem minerals from the previously MATCHed list.

The 20 most likely gem minerals can be viewed with the TABULATE command. This command will by default tabulate the TM index (from highest to lowest) and the properties which

were specified for the identification process. Alternatively, this command may be used for tabulation of properties not used in the search. The procedure for the use of the TABULATE command is given in table 3-15.

The TABULATE command can be used after any of the MATCH, IDENTIFY, MATCH AND, or IDENTIFY AND procedures have been completed. In addition, the list of likely candidates may be tabulated alphabetically, by issuing the SORT command prior to the TABULATE command.

After the identification process has been completed the COMPILED RECORD of any of the likely candidates may be obtained with the DISPLAY command (e.g., display compiled dravite). This command may also be used for viewing of SAMPLE and GENERAL DATA DISPLAYS of any of the MATCHed or IDENTIFied gem minerals. The procedure for obtaining such a DISPLAY is given in table 3-16. Alternatively, the contents of RECORDS may be viewed with the SHOW command. This command results in the listing of each parameter rather than DISPLAYing the entire RECORD containing the parameters. A summary of the SHOW command is given in table 3-17. The SHOWWHAT variable controls which parameters are listed with the SHOW command. The options available for this variable are:

SHOWWHAT = BOTH.....lists both full and empty fields ;
SHOWWHAT = FULL.....lists only full fields; and
SHOWWHAT = EMPTY....lists only the empty fields.

The last available option on the SHOWWHAT variable has been used extensively in listings of missing data in the data base; however, it is an option that is of little use to most users of the GemIdent data base. Examples illustrating the different possible approaches to gem identification using GemIdent are presented in the next chapter.

ERRORS IN THE GEMIDENT DATA BASE

It is inevitable that data bases will contain some errors. The majority of errors are inherent to the present state of data compilation, and several potential sources of error are involved in data base development. These are: literature errors, interpretation errors, abstracting and input errors.

Literature errors are perhaps the most difficult type of error to detect in a data base. Errata of this type may be due to misprinting or they may in fact represent author errors. Author errors are in many instances, cases where insufficient characterisation has led to erroneous conclusions. Since data on each gem was collected individually, visual comparison of gem data from various literature sources was possible, therefore limiting the presence of this source of error in the data base. Of

course, this kind of comparison is not feasible when the number of individual RECORDS with many data items is large. Since most gems in the data base have fewer than a total of 10 SAMPLE and GENERAL RECORDS, visual comparisons were in most cases convenient. In addition, the corrigendum of each of the volumes of the Journal cf Gemmology were also checked for reported errors. Where reviews with further characterisation of gem minerals have taken place, all data related to previously published sources of data were checked and where necessary deleted or edited in favour of the most recent determinations (e.g., taprobanite and taaffeite).

Interpretation errors generally stem from ambiguities in the literature. For example, orientationless refractive indices and pleochroic schemes are commonly encountered in the gemmological literature, and these had to be assigned to their respective vibration directions based on previously known values. Another example involves partial analyses where the low sum totals of weights suggest the presence of other elements. Once again, based on previously determined values, missing weight percentages, for example of water, were calculated by difference from 100 wt.%. Usually a comment about the interpretations may be found in the REMARKS FIELD. There may be a small number of errors in the data base associated with such interpretations.

Abstracting and input errors are inherent to the present process of transfer of data from the literature to the data files; and they are the most problematic, since incorrect data results in erroneous identifications. These types of errors usually reveal themselves in identification procedures, where clearly false MATCHes are presented as likely candidates due to the presence of incorrect data in the data base.

Input errors are minimized in the GemIdent program by special compatibility algorithms. In these algorithms the compatibility of some fundamental parameters is ensured. Thus, once the symmetry of a gem mineral is specified, the optical character is set by the program. Subsequent entry of refractive indices and pleochroic schemes must use compatible syntax. The optical signs implied by all SAMPLE and GENERAL refractive indices must also be consistent. If a gem mineral is known to have positive and negative optical signs, this must be assigned directly. The compatibility checks performed by the GemIdent program for biaxial, uniaxial, and isotropic gems are shown in figure 3-6.

One additional feature that limits input errors of compositional weight percentages, is the WEIGHT SUM parameter. If the weight sum of oxides or elements entered from the literature is not identical to that calculated by the program, an error message is given. The majority of

weight sum errors are not entry errors and are, in fact, associated with the literature.

During the course of the GemIdent data base development, systematic and random checks were conducted for all numerical data. As more convenient methods for transfer of data from the literature to data bases become available, these sources of errors are likely to decrease in all literature based data bases.

OTHER GEM DATA BASE

A paper presented in the 1980 Federal Gemmological Conference in Melbourne outlined for the first time, how computers can be used as a tool in gemmology (Barrington 1981). Two data banks were conceptualised. The first was a Library Catalougue data bank which would contain all gemstones of a given collection, and the second was a National Standard Reference data bank containing similar data but with limits of the ranges presented in Visual Display Units. It appears that the idea of the Visual Display Units of the National Standard Reference are much like the COMPILED DATA DISPLAYS of GemIdent. Moreover, the Library Catalougue data bank seems to be much like the SAMPLE RECORDS part of the GemIdent data base. Unfortunately, no further actions were taken despite the

realisation of the value of the applications of data banks in gemmology.

Only one other gem data base and identification program has been developed and it is called GEMDATA (Read 1983, 1987). The data base has 224 gems and identifications can be based on any of the following properties: colour (an arbitrary colour system), transparency, refractive index (minimum and maximum values), optic sign and specific gravity.

The pseudo-menu driven program consists of five different programs. These are the Gem Identification, Gem Data Page, Gem Comparisons, Gem Constants, and Gem Calculations programs.

The Gem Identification program requests TEST DATA (equivalent to GemIdent UNKNOWN DATA), which may be in the form of numerical values as well as number codes (e.g., positive optic-sign=code 1 etc.). The program offers two choices of search limits referred to as the NARROW and WIDE SEARCHES, where different margins of error are assigned to the input data prior to the actual search. At the end of the search, the INDEX NUMBERs of all appropriate gems together with their refractive indices, optical sign, and specific gravity are listed. If no match is found a message to that effect is displayed.

The INDEX NUMBERs of the gems may be used in the Gem Data Page program to retrieve more information. GEM DATA PAGEs contain the following data: formula, symmetry, transparency, dispersion, refractive index (orientationless), colour, pleochroism (orientationless), absorption spectra, fluorescence, density, hardness, habit, cleavage, and occurrence.

The Gem Comparison program is used to compare gem data. It is essentially equivalent to the GemIdent TABULATE parameter where the INDEX NUMBER of gems are used to retrieve and tabulate gem data.

GEMDATA also contains tables of constants, and the Gem Constants program offers options for tabulating selected gems in alphabetical order, or in order of increasing refractive indices and specific gravities.

The last program available in GEMDATA is called Gem Calculations and it contains the necessary details for the following calculations:

- Specific gravity using Archemides principle
- Fresnel's formula relating surface reflectivity to the refractive index in a chosen medium.
- Critical angle
- Brewsters angle of polarization for a particular index value (arctan RI of reflecting material).

Recently, the GAA (Gemmological Association of Australia) Board of Studies and Examination evaluated the Gem Identification program of GEMDATA (McCaughtrie 1989). The TEST DATA of optical sign, refractive index, transparency, specific gravity, and colour were found to be too limited to allow for conclusive identifications to be made, and the margins of error assigned by the program did not allow for inaccuracies in measurement. Where the values of the TEST DATA were outside the limits available in the data base, the result were either an incorrect identification, or a message indicating that 'no match' was found. This was partly attributed to the fact that the minimum and maximum values of data included in the GEMDATA data base did not take into account the unusually high or low values. The colour data was also found to be inadequate since only 12 colours were included and thus it was inevitable that complete overlap between the input data and that available in the data base would not occur at all times. The overall conclusion of this evaluation was that the Gem Identification program of GEMDATA could not take the place of systematic analysis of all available data in a gem identification task.

Table 3-1: A summary of GemIdent allowable colour entry terms used for specification of pleochroic and fluorescence colours.

Context:	format of colour entry for DC, DCR, DCOmega, DCEpsilon, PLC, PCAlpha, PCBeta, PCGamma, FLR, FLWuv, FSWuv, FXRay general, sample and unknown data.					
(colour):	((tone)) ((hue)) (hue)					
(tone):	Dark, Deep,	D	PALe, Light,	L		
(hue):	BLAck,	BK	BLUe, BLUish,	BU	BRownish,	BR
	Colourless,	CL	GREEnish,	GN	GREYish,	GY
	LILacish,	LL	Orange,	OR	PInkish,	PK
	PUrple, Purplish,	PP	Reddish,	RD	Violet,	VT
	White,	WT	Yellowish,	YL		
	INert	IN (Fluorescences)				
Examples:	green, pale green, bluish green, light bluish green					
Note:	Blue green is a different colour than green blue. Also, the use of the "ish" ending has no effect, i.e., green and greenish are equivalent. In DISPLAYs and TABULATions only the above abbreviations for tone and hue are given.					

Table 3-2a: The ColorMaster Hues and their usage in GemIdent.

Forms:	COLORMASTER-Hues CMHues	
Context:	unknown data; sample ColorMaster-colour data; tabulate parameter	
(hue):	#	ColorMaster Hue Terms / Abbr.
	01	Purple — P
	02	reddish Purple — r P
	03	Red-Purple/Purple-Red — RP/PR
	04	strongly purplish Red — st p R
	05	slightly purplish Red — sl p R
	06	Red — R
	07	orangy Red — o R
	08	Red-Orange/Orange-Red — RO/OR
	09	reddish Orange — r O
	10	Orange — O
	11	yellowish Orange — y O
	12	orangy Yellow — o Y
	13	Yellow — Y
	14	greenish Yellow — g Y
	15	Yellow-Green/Green-Yellow — YG/GY
	17	yellowish Green — y G
	18	slightly yellowish Green — sl y G
	19	Green — G
	20	very slightly bluish Green — v sl b G
	21	slightly bluish Green — sl b G
	22	strongly bluish Green — st b G
	23	Green-Blue/Blue Green — GB/BG
	24	very strongly greenish Blue — v st g B
	25	greenish Blue — g B
	26	very slightly greenish Blue — v sl g B
	27	Blue — B
	28	violetish Blue — v B
	29	bluish Violet — b V
	30	Violet — V
	31	bluish Purple — b P
	32	Orange-Brown — OBrn
	33	Yellow-Brown — YBrn
	34	orangy Brown — o Brn
	35	yellowish Brown — y Brn
Note:	spaces must appear between abbreviations, i.e., GemIdent	
Usage:	CMH displays value CMH=(hue)... assigns value tabulate CMH tabulates value	

Table 3-2b: ColorMaster tone and its usage in GemIdent.

Forms:	COLORMASTER-Tone CMTone
Context:	sample ColorMaster-colour data; tabulate parameter
Def:	the dimension of colour that relates to the lightness or darkness of a colour sensation. There are 11 tones but only 7 (tone 2 through 8) are used in grading the transparent coloured gems.
(tone):	

#	ColorMaster Tone Terms	Abbr	#	ColorMaster Tone Terms	Abbr
00	colorless/white	c/w	06	medium dark	m dk
01	extremely light	ex l	07	dark	dk
02	very light	v l	08	very dark	v dk
03	light	l	09	extremely dark	ex dk
04	medium light	m l	10	black	bl
05	medium	m			

Usage:	tabulate CMT tabulates value

Table 3-2c: ColorMaster saturation and its usage in GemIdent.

Forms:	COLORMASTER-Saturation CMSaturation
Context:	sample COlorMaster-colour data; tabulate parameter
Definition:	The dimension of colour that relates to the "strength" or "intensity" of the colour sensation. Warm colours (red, orange, yellow, brown) tend to be brownish when desaturated, while cold colours (blue, green, violet) tend to be grayish when desaturated, thus two separate saturation word scales exist.
(saturation):	# ColorMaster Saturation Terms Abbr. 1 grayish/brownish gr/br 2 slightly grayish/ sl gr/ slightly brownish sl br 3 very slightly grayish/ v sl gr/ very slightly brownish v sl br 4 moderately strong m st 5 strong st 6 vivid v
Usage:	tabulate CMS tabulates value

Table 3-2d: ColorMaster color usage in GemIdent.

Forms:	COLORMASTER-COlour CMCOlour CMCOlor
Def:	The GIA's Colored Stone Grading System is used to describe the colour of transparent coloured gems that are routinely seen in the marketplace.
Context:	Sample data; tabulate parameter.
Usage:	CMCOlour displays value CMCOlour=(colour)(,(colour))(,(colour)) assigns value tab COLORMASTER-COlour ¦CMCOlour tabulates all values tab COLORMASTER-Cause ¦CMCause tabulates sub-value tab COLORMASTER-STrength ¦CMSTrength tabulates sub-value tab COLORMASTER-Notation ¦CMNotation tabulates sub-value tab COLORMASTER-Hue ¦CMHue tabulates sub-value tab COLORMASTER-Tone ¦CMTone tabulates sub-value tab COLORMASTER-Saturation¦CMSaturation tabulates sub-value (colour): (CMCause) (CMSTrength) ((HTS)¦(CMNotation)) (HTS): (CMHue) (CMTone)/(CMSaturation)
Example:	colour=dominant OR 3/4 colour=dominant C 34 58 22,change weak G 14 48 12
Note:	GemIdent converts between the HTS and CMN notations. When a stone has no additional colours, it is not nesessary to specify the strength. If a stone has an additional colour, it is separated from the dominant colour with a comma, as shown in second example. The sample ColorMaster-hues are compiled and matched/ identified with the unknown ColorMaster-hues.

Table 3-3: The cause of additional colours that are graded with the ColorMaster, together with their usage in GemIdent.

Forms:	COLORMASTER-Cause CMCause
Context:	tabulate parameter; sample ColorMaster-colour data
{cause}:	Dominant|Change|Pleochroism|Shift|Windowing| Zoning Dominant is the default cause. The dominant or key colour of a gem is always graded with the GIA's Colored Stone Grading System. Where additional colours are present and are moderate to strong, caused by colour change, pleochroism, shift, windowing or zoning, they must also be graded. These additional colours are defined as: A) Colour change is a visible difference in the colour of a gem under the daylight equivalent and the incandescent light source of the ColorMaster. B) Pleochroism is the phenomenon that results from double refraction and tends to concentrate at the ends or tips on a faceted gem, when viewed under the daylight equivalent light source. C) Colour shift is an additional colour, often higher in saturation than the dominant colour, seen in singly refractive stones under the daylight equivalent light source. D) Windowing is present often in the center of poorly cut stones, and while it usually has the same hue and tone as the dominant colour, it is less saturated. E) Colour zoning is only graded when the stone has been purposely cut in order to juxtapose areas of different colour. Only intended colour zoning is graded with the ColorMaster.
Usage:	tabulate CMC tabulates value

Table 3-4:The specification of the strength of the additional ColorMaster colours in GemIdent.

Forms:	COLORMASTER-STrength CMSTrength CMR
Context:	sample ColorMaster-colour data; tabulate parameter
{strength}:	Weak¦Moderate¦Strong¦Vague¦Distinct¦SHarp¦{none} {none} valid only for non-dominant caused colours The strength of the additional colours caused by colour change, pleochroism, colour shift and windowing is described as being weak, moderate or strong. The demarcation between the two colours present (it is arbitrary which colour is entered as dominant or additional) is described by the terms vague, distinct or sharp.
Usage:	tabulate CMST tabulates value

Table 3-5: Abbreviations of institutions and museums used in GemIdent for specification of the collection number parameter.

AU	Australian Museum
BYU	Brigham Young University
CT	California Institute of Technology
GIA	Gemological Institute of America
HMM	Harvard Mineral Museum
NMHS	National Museum of Natural History
PC	Private Collection-Name/Country
UAMM	University of Arizona Mineralogical Museum
UCMM	University of Cambridge Mineralogical Museum
USNM	United States National Museum

Table 3-6: List of terms which can be explained with the online HELP facility.

#	$	*	-	:
?	@	A	ABBreviations	
ABSorption-spectra		ADD	ALL	ALPha
ANGLE-ENTRY	ANGLES	ASPectra	ATTENtion	AVErage
B	BATCH	BETa	BIAXIAL	BIRefringence
BLAnk	BREAk	BREXtinction	BRGrade	BRILLIANCE
BRILLIANCE-Extinction		BRILLIANCE-Grade		
BRILLIANCE-Light-return		BRILLIANCE-Windowing		BRLReturn
BRWindowing	C	CASE	CHAracter	
CHAracters-per-line		CLARity	CLARITY-Description	
CLARITY-Grade	CLARITY-Type	CLASSify	CLDescription	CLGrade
CLType	CM	CMAster	CMCause	CMH
CMHUe	CMNotation	CMR	CMSaturation	CMSTrength
CMTone	CN	CNRECords	COLLECTion-number	
COLOR	COLORMASTER-Cause		COLORMASTER-COlour	
COLORMASTER-Hues		COLORMASTER-Notation		
COLORMASTER-Saturation		COLORMASTER-STrength		
COLORMASTER-Tone		COLORS	COLOUR	COLOUR-ENTRY
COLOURS	COMMAND	COMMANDS	COMMENTS	COMPILE
COMPILED Data	CONTINUATION	CONTINUE	COPYRIGHTs	CPL
CTGrade	CTLength	CTType	CTWEight	CTWIdth
CUT	CUT-Depth	CUT-Grade	CUT-Length	CUT-Type
CUT-WEight	CUT-WIdth	DATA	DATA Types	DATE
DC	DCEpsilon	DCOmega	DCR	DCRS
DEFAULT	DEFAULTS	DELETE	DENsity	DEPth
DESTROY	DICHROIC-COLOUR(Epsilon)		DICHROIC-COLOUR(Omega)	
DIChroism	DICHROISMS	DICHROScope-colour		DIMension
DINitials	DISCREDited	DISPersion	DISPLAY	DISPLAYING
DIVisions	DOS	DPT	DSP	ECHo
EDGes	EDIT	EDITING	ELIST	EPSilon
ERRORs	EXIT	EXPLAIN	EXTinction	FINISH
FINISH-Facet-survey			FINISH-Grade	FINISH-Polish
FINISH-Symmetry				
FLR	FLRS	FLUORESCENCE		
FLUORESCENCE(Long-Wave-Ultraviolet)				
FLUORESCENCE(Short-Wave-Ultraviolet)			FLUORESCENCE(X-Ray)	
FLUORESCENCES	FLWuv	FNFsurvey	FNGrade	FNPolish
FNSymmetry	FORmula	FORMULA-ENTRY	FRM	FSWuv
FXRay	GAMma	GemIdent	GENERAL Data	GENERALS
GRECords	HELP	HEXagonal	HUE	IDENT SECTION
IDENTIFIER	IDENTIFY	IGNORED	IM	INClusions
INDices	INITIals	INTRODUCTION	IOXygen	ISOMETRIC
ISOTROPIC	LCUTOff	LENgth	LEVel	LIGht-return
LIST	LNGth	LOCality	LOCATion	LVL
MATCH	MAXimum	MERGE	MINERAL	MINERAL Data
MINIMum	MISmatch	MOHs	MONoclinic	MOVE

Table 3-6: continued

MRECords	N	N(Alpha)	N(Beta)	N(Epsilon)
N(Gamma)	N(Omega)	NALpha	NAMe	NBEta
NEPsilon	NGAmma	NOMega	NSM	NULLs
NUMber	OCCurrence	OF	OMEga	OPC
OPM	OPSign	OPTICAL-Character		OPTICAL-Sign
ORThorhombic	OTAppeal	OTBalance	OTGrade	OUTLINE
OUTLINE-Appeal	OUTLINE-Balance		OUTLINE-Grade	OUTPut
OXides	PAUse	PBASE	PBASIS	PCAlpha
PCBeta	PCGAmma	PFBAlance	PFBUlge	PFChpd
PFGrade	PFGThickness	PFK	PLC	PLCS
PLEOCHROIC-COLOUR(Alpha)		PLEOCHROIC-COLOUR(Beta)		
PLEOCHROIC-COLOUR(Gamma)		PLEOchroism	PLEOCHROISMS	PPGrade
PRECISION	PROfile	PROFILE-BAlance		PROFILE-BUlge
PROFILE-Crown-height/pavillion-depth			PROFILE-GIrdle-thickness	
PROFILE-GRade	PROFILE-Ratio	PROFILE-Table-size		PROMPTs
PROPORTION-Basis		PROPORTION-Grade		
PROPORTION-Sum				
PSUM	Quit	RANGE	RECords	
REFractive-index		REFractive-indices		REMarks
REQuests	RI	SAMPLE Data	SAMPLEs	SATuration
SAVE	SHOW	SHOWWhat	SIGN	SORT
SOURCE	SPEctra	SRC	SRECords	STATUS
STop	SUBSET	SUGGESTions	SUM	SYMBOLS
SYMmetry	SYNONYM Data	SYNONYMs	SYNTAX	SYStem
TABle	TABULATE	TEST	TETragonal	TIMe
TITLE	TLIST	TM	TONE	TOTal
TRAnsparency	TREE	TRIClinic	TRIGonal	TRN
UNIaxial	Unknown	UNKNOWN Data	USAGE	VARiables
VERTICAL BAR	WCUToff	WDTh	Weight	WGT
WIDth	WINdowing	YRECords	ZERo	¦

Table 3-7: Examples of some typical tabulations of the MREC, SREC, GREC and YREC commands.

MREC TAAFFEITE

#	Rec#	#Sa	#Ge	Name
1	348	13	2	TAAFFEITE

SREC KORNERUPINE

#	Rec#	Source
1	278	Schweiz. Mineral. Petrog. Mitt. v.56, p.65-68
2	279	Z. Dt. Gemmol. Ges. v.23, p.258-278
3	280	Min. Mag. v.26, p.119-130
4	281	Min. Mag. v.26, p.119-130
5	282	Min. Mag. v.26, p.119-130
6	283	Amer. Min. v.37, p.531-541
7	284	Amer. Min. v.37, p.531-541

GREC PREHNITE

#	Rec#	Source
1	246	Aust. Gemmol. v.15, p.258-259
2	268	Arem (1987) Encyl. Gems.
3	552	Webster (1983)
4	813	Deer et al. (1962) v.3, p.263

YREC VESUVIANITE

#	Rec#	Synonym	Accepted name
1	31	VESUVIANITE	IDOCRASE
2	673	VESUVIANITE-JADE	CALIFORNITE

CNREC CT

#	Collection Number	REC#	Name
1	CT-31A	1219	ALBITE
2	CT-31B	1220	ALBITE
3	CT-33	1222	CLEAVELANDITE

Table 3-8: Summary of the GemIdent Subset command.

Form:	SUBSET	
Context:	GemIdent command available anytime; tabulate parameter	
Usage:	SUBSET	displays number of minerals in subset minerals
	SUBSET Load (file)	quickly loads the subset minerals pointers
	SUBSET Off	empties the subset; use the entire data base
	SUBSET Read (file)	slowly read the subset mineral names
	SUBSET Save (file)	quickly saves the subset mineral pointers
	SUBSET Transfer	quickly transfers the MATCHed/ IDENTified minerals to the subset
	SUBSET Write (file)	slowly writes the subset mineral name
	tab SUB (pars)...	tabulates parameters for the subset
Note:	A subset is normally created by READing it in once, as this is slow. It is then SAVEd to a file. On subsequent occasions, it is quickly loaded rather than slowly read. Subsets have been created so that a restricted group of minerals can be examined. This may be useful for teaching purposes or when it is known that only a restricted number of minerals need be considered in a particular application. Use of subsets can cut processing time dramatically.	

Table 3-9: Gem minerals in subset A and B represent the most commonly encountered gems in the market place.

GROUP A		GROUP B	
ALEXANDRITE	LIZARDITE	ACTINOLITE	LAZULITE
ALMANDINE	MALACHITE	AMBLYGONITE	LEUCITE
AMAZONITE	MICROCLINE	ARAGONITE	MAGNESIOAXINITE
ANDALUSITE	MOLDAVITE	AZURITE	MARIALITE
ANDRADITE	MORGANITE	BARITE	MEIONITE
ANTIGORITE	NEPHRITE	BENITOITE	MIZZONITE
AQUAMARINE	OLIGOCLASE	BERYLLONITE	NATROAPOPHYL-LITE
BERYL	ORTHOCLASE	BRAZILIANITE	NATROLITE
BIXBITE	ORTHOCLASE-MOONSTONE	BRONZITE	PECTOLITE
BUERGERITE	PERIDOT	CASSITERITE	PETALITE
CALCITE	PYROPE	CHAROITE	PHENAKITE
CHRYSOBERYL	QUARTZ	CHRYSOCOLLA	PHOSPHOPHYLLITE
CORDIERITE	RHODOCHROSITE	CUPRITE	POLLUCITE
CORUNDUM	RHODOLITE	DANBURITE	PREHNITE
DIAMOND	RHODONITE	DATOLITE	PROSOPITE
DIOPSIDE	RUBY	DIOPTASE	PUMPELLYITE
DRAVITE	SAPPHIRE	DIPYRE	PYRITE
ELBAITE	SCHORL	DUMORTIERITE	SCHEELITE
EMERALD	SODALITE	ENSTATITE	SHATTUCKITE
FLUORITE	SPESSARTINE	EPIDOTE	SILLIMANITE
GOSHENITE	SPINEL	EUCLASE	SINHALITE
GROSSULAR	SPODUMENE	FERROAXINITE	SMITHSONITE
HELIODOR	TANZANITE	FLUORAPATITE	SPHALERITE
HEMATITE	THULITE	FLUORAPOPHY-LLITE	SPHENE
HESSONITE	TOPAZ	GAHNITE	SUGILITE
HIDDENITE	TSAVORITE	GAHNOSPINEL	TAAFFEITE
IDOCRASE	TSILAISITE	GYPSUM	TALC
JADEITE	TURQUOISE	HEMIMORPHITE	THOMSONITE
KUNZITE	UVITE	HOWLITE	TREMOLITE
LABRADORITE	ZIRCON	HYDROXYAPOP-HYLLITE	TUGTUPITE
LAZURITE	ZOISITE	HYDROXYLA-PATITE	VARISCITE
LIDDICOATITE		KORNERUPINE	WILLEMITE
		KYANITE	WULFENITE

Table 3-10: Synonyms beginning with prefix "Orient"

YREC ORIENT

#	Rec#	Synonym	Accepted name
1	493	ORIENTAL-AGATE	AGATE
2	494	ORIENTAL-ALABASTER	CALCITE
3	495	ORIENTAL-ALMANDINE	SAPPHIRE
4	496	ORIENTAL-AMETHYST	SAPPHIRE
5	497	ORIENTAL-AQUAMARINE	SAPPHIRE
6	498	ORIENTAL-CAT'S-EYE	
7	499	ORIENTAL-CHALCEDONY	CHALCEDONY
8	500	ORIENTAL-CHRYSOBERYL	SAPPHIRE
9	501	ORIENTAL-CHRYSOLITE	
10	502	ORIENTAL-CORNELIAN	CORNELIAN
11	740	ORIENTAL-EMERALD	SAPPHIRE
12	503	ORIENTAL-SAPPHIRE	SAPPHIRE
13	504	ORIENTAL-TOPAZ	SAPPHIRE

Table 3-11: Classification of the garnet group

```
TREE GARNET-GROUP FULL

GEMS top
 SILICATES type
  NESOSILICATES class
   GARNET-GROUP group
    ANDRADITE-GROSSULAR-SERIES series
     GROSSULAR species
      HESSONITE variety
      TSAVORITE variety
     ANDRADITE species
      DEMANTOID variety
      TOPAZOLITE variety
    PYROPE-ALMANDINE-SERIES series
     RHODOLITE variety
     PYROPE species
      CHROME-PYROPE variety
     ALMANDINE species
    ALMANDINE-SPESSARTINE-SERIES series
     ALMANDINE species
     SPESSARTINE species
    PYROPE-SPESSARTINE-SERIES series
     PYROPE species
      PYROPE-SPESSARTINE-CC variety
      MALAIA variety
```

Table 3-12: Summary of the GemIdent classify command.

Form:	CLAssify
Def:	The classification of a gem division within the gemstone hierarchy.
Context:	Mineral and unknown data; tabulate parameter
Usage:	CLA shows classification CLA (AS) {level} (OF) {division} ({division}) classifies gemstone tabulate LEVel tabulates level tabulate DIVision tabulates divisions
{level}:	TOp, Mineral, TYpe, Class, Family, SUPer-group, Group, SUB-Group, SEries, End-member, species, SUB-Species, Polytypes, Variety.
Note:	The TREE command displays the classification hierarchy for a gem. The level and second division for an unknown are ignored, however, the first division will restrict MATCHing and IDENTification to gems classified within that division, i.e., an unknown classified under feldspars would restrict scanning to feldspars, plagioclase and alkali-feldspars.

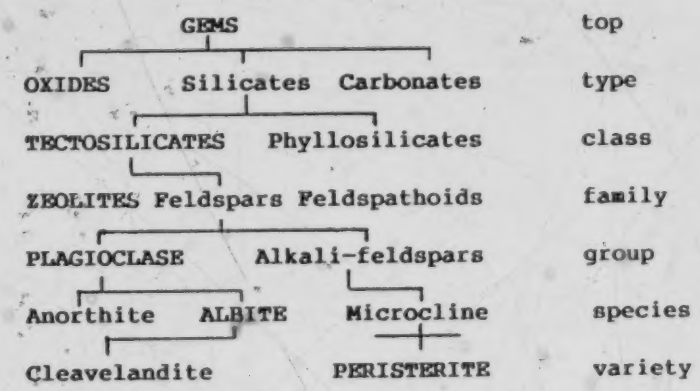


Table 3-13: Summary of the GemIdent tree command.

Form: TREE

Def: "trees" show a mineral's position in the classification hierarchy.
Trees normally have the following form:

```
                          A   B    - SPECIES level
                         /\ / \
(D is abnormal being)   /  C D  E  - SUB-SPECIES level
(within 2 divisions)   /  / /
                      F  G H I     - VARIETIES level
```

GemIdent prints trees sideways. A path from the mineral to the top of the tree is shown. A few minerals, such as D above, have two possible paths upwards. For such minerals, which will be postscripted by an "*", only one path will be traced. To trace the other path, specify "alternate". Also, all the minerals one level lower will be shown. To see the minerals more than one level lower, specify "full". Note: F is considered to be one level lower than A.

Context: GemIdent command available anytime

Usage: TREE (mineral) (Full) (Alternate) shows the classification hierarchy "tree"

TREE A	TREE A FULL	TREE H	TREE H ALT
A species	A species	A species	B species
F variety	F variety	D sub-species *	D sub-species *
C sub-species	C sub-species	H variety	H variety
D sub-species	G variety		
	D sub-species		
	H variety		
	I variety		

Table 3-14: Summary of GemIdent add command.

Form:	ADD	
Def:	Command to add data to GemIdent	
Context:	GemIdent command request loop.	
Usage:	Add General {mineral}	adds general and mineral data. Enters the "General/mineral input" request loop.
	Add Sample {mineral}	adds sample and mineral data. Enters the "Sample/mineral input" request loop.
	Add Mineral {mineral}	adds mineral data. Enters the "Mineral input" request loop.
	Add Any {mineral}	adds general, sample and mineral data.Enters the "General/mineral/sample input" request loop. General parameters should be prefixed with "General." to distinguish them from sample parameters. Ex:g.den=3.4
	Add SYnonym {synonym}	adds synonym data. Enters the "Synonym input" request loop.
Note:	The SAVE command must be issued to complete the addition of data. An ATTENtion will abort the addition of data.	
Ex:	add mineral azurite add general spinel add synonym disthene	add sample painite add any dravite

Table 3-15: Summary of GemIdent tabulate command.

Forms:	Tabulate, Table
Context:	GemIdent command request loop
Usage:	T ({pars}|{tpars})... tabulate parameters for minerals
{pars}:	Any COMPILED, GENERAL, MINERAL, SAMPLE, SYNONYM or UNKNOWN data. Also: ANGles, BLAnk, BRILLiance, CLArity, CM, CMColours, CUT, DATA, DICHROISMS, DIMensions, EDGes, FINISH, FLUORESCENCES, LEVel, NM, NUMber, OPM, OUTline, PARents, PLEOCHROISMS, PROfile, RECord, RIs, TM, SUM
{tpars}:	ALL, AVErage, CHAracters-per-line, DEFault, GENerals, LENgth, LINes-per-page, MAXimum, MINimum, OF, SAMples, SUBset, SYNonym, UNKnown
Ex:	t nam den w SiO2 w Al2O3 — tabulates the names, densities and weights of SiO2 and Al2O3 of all MATCHed/IDENTified minerals.
	t w K w Ca for of amazonite — tabulates the formulae and weights of K and Ca for amazonite.

Table 3-16: Summary of the GemIdent Display command.

Form:	Display	
Def:	Generates full page data displays.	
Context:	GemIdent command request loop.	
Usage:	D All ({type})	displays for all minerals
	D General {record}	displays for specified general. See GRECords.
	D (MAtched) ({type})	displays for all MATCHed or IDENTified minerals
	D (Mineral) ({type}) {mineral}...	displays for specified minerals
	D Sample {record}	displays for specified sample. See SRECords.
	D SUbset ({type})	displays for mineral subset
	D UNDisplayed ({type})	displays for all minerals modified after last D UNDisplayed
	D Unknown	displays for unknown
{type}:	Compiled	Compiled (min/ave/max) and mineral data is displayed. This is the default type if none specified.
	Generals	General (min/max) and mineral data is displayed.
	Samples	Sample and mineral data is displayed.
Notes:	- The date displayed is the date data was last modified. - The standard deviations of compositions will be shown only when more than five analyses have been used (compiled data).	

Table 3-17: Summary of the GemIdent show command.

Form:	Show	
Context:	"GemIdent command" request loop	
Usage:	S Compiled (Generals) (Samples) {mineral}...	shows compiled/mineral and possibly sample/general data for specified minerals
	S General {general}	shows mineral/general data for specified generals. See GRECords.
	S Sample {sample}	shows mineral/sample data for specified samples. See SRECords.
	S Matched	shows compiled/mineral data for MATCHed/IDENTified minerals
	S Unknown	shows unknown data
Note:	The date displayed is the date data was last modified. For compiled data, minimum, average and maximum parameter values are shown. The standard deviations of compositions is shown only when more than five analyses have been used. For general data, minimum and maximum parameter values are shown. Show respects the WIDTH variable.	

Figure 3-1: A Sample Data Display of Tsavorite

Page: 1 Sample/Mineral Data Display

1277	Name: TSAVORITE variety of GROSSULAR							
Formula: Ca3Al2Si3O12								
Symmetry: Cubic			Transparency:			2:09:37MAY 23, 1990		HO
El	Weight	At Prop	A	B	C	alpha	beta	gamma
						90.0	90.0	90.0
O	42.100	12.000*						
Ca	26.137	2.974	n			Biref.	Density	MOH
Si	18.123	2.943	1.74			0.0	3.63	
Al	10.860	1.836						
V	1.625	0.145	Disper.	OPC	OPS			
Mn	0.434	0.036		Isotrop				
Ti	0.330	0.031						
Mg	0.259	0.049	DC			FLWuv	FSWuv	FXRay
Cr	0.123	0.011						
Fe	0.070	0.006						
Σ	100.06	20.03						
Absorption Spectra: 420.0,590.0,.....								
Source: Stockton & Manson (1985) Gems Gemol., v.21, p.205-218								
Inclusions:								
Remarks:								
Occurrence:								
Locality: Unknown.								
Collection Number: GIA-13319C								

Figure 3-1: Continued....

Page: 2 Sample Grading Data Display

Rec: 1277	TSAVORITE variety of GROSSULAR			
Cut	Type:			Grade:
	Length: mm	Width: mm	Depth: mm	Weight: ct
Clarity	Description:			Grade:
				Type:
Face-up Outline	Balance:			Grade:
	Appeal:			L/W:
Profile	Girdle Thickness:			Grade:
	Total Depth: %		Table Size: %	
	Bulge:		Balance:	
	Crown Height/Pavillion Depth:			
Brilliance	Light Return: %			Grade:
	Windowing: %		Extinction: %	
Proportion	(Outline + Profile + Brilliance) / 3			Grade:
Finish	Polish:			Grade:
	Symmetry:		Facet Survey:	

ColorMaster	Colour	1	2	3
	Cause			
	Strength			
	Hue			
	Tone			
	Saturation			
	CM Notation			

Figure 3-2: The Compiled Data Display of Enstatite.

Page: 1 Compiled/Mineral data display

130	Name: ENSTATITE species of ENSTATITE-HYPERSTHENE-SERIES										
Formula: Mg2Si2O6											
Symmetry: Orthorhombic		Transparency: TP							Date: 14:59:40APR 19, 1990		
Samples: 16	Generals: 3	Total Samples: 16									

El	Wt Min	Wt Ave	Wt Max	Std Dev	At Prop
O	45.446	46.690	47.836	0.675	3.000*
Si	24.980	26.473	27.836	0.985	0.969
Mg	19.782	21.247	23.093	1.274	0.898
Fe	0.000	3.454	5.791	1.641	0.064
Al	0.000	1.477	3.493	0.976	0.056
Ca	0.000	0.332	0.786	0.307	0.009
Cr	0.000	0.260	0.616	0.273	0.005
Mn	0.000	0.084	0.139	0.051	0.002
Ti	0.000	0.028	0.090	0.027	0.001
Na	0.000	0.022	0.067	0.022	0.001
K	0.000	45 ppm	0.025	86 ppm	0.000
Σ	90.207	100.071	109.772		5.004

a	b	c	alpha	beta	gamma
18.232	8.808	5.180	90.000	90.000	90.000

NAlpha	NBeta	NGamma	Birefri	Density	MOH
1.650	1.653	1.658	0.0	3.2	5.0
1.658	1.661	1.668	0.01	3.276	5.75
1.665	1.671	1.680	0.03	3.37	6.0

Disper.	OPC	OPS
	Biaxial	+

PCAlpha	PCBeta	PCGamma	FLWuv	FSWuv	FXRay
L Rd Br	L Gn Br	L Gn	In	In	
Pp	L Rd Yl	Gn			
Br Pk	L Br Yl	Rd Br			
Rd Br	Gn Br				
Gn Br	Yl Br				
L Br	Br				

Absorption Spectra: 449.0,455.0,459.0,483.0,488.0,502.5,503.0,506.0,507.0,509.0,510.0,
543.0,547.0,547.5,550.0,555.0,...

ColorMaster-Hues: , , , , , , , , ,

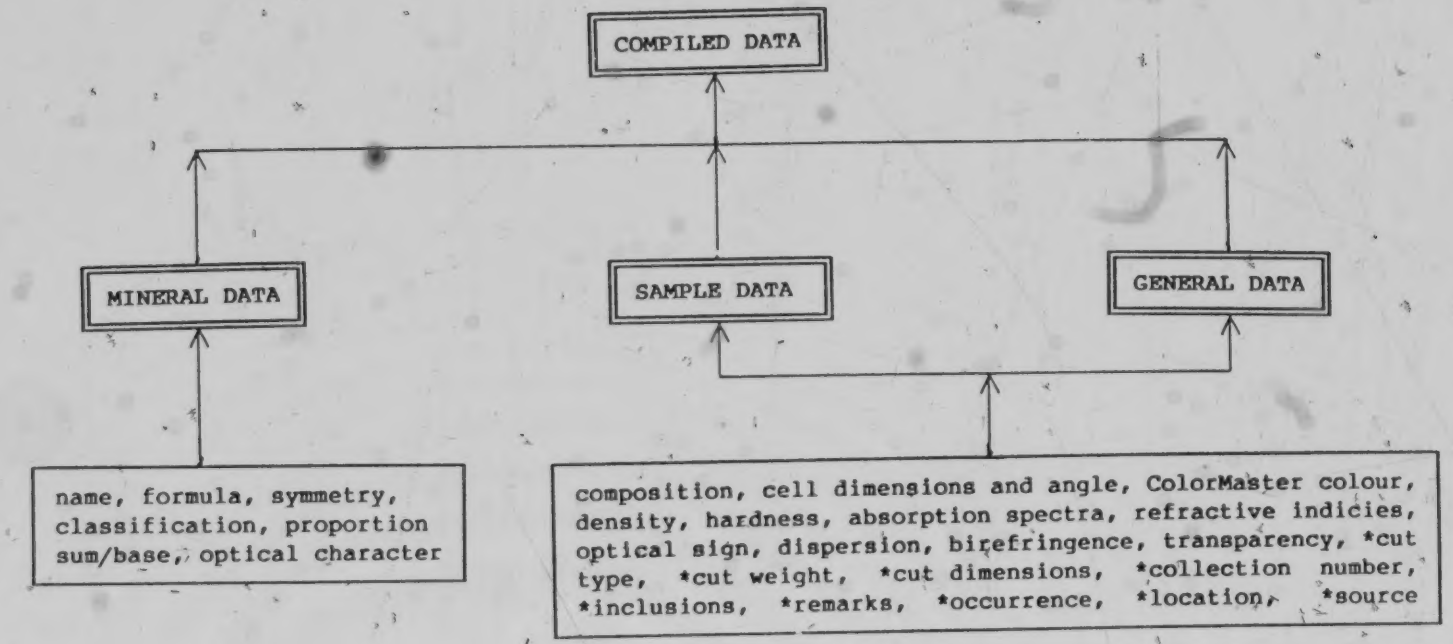
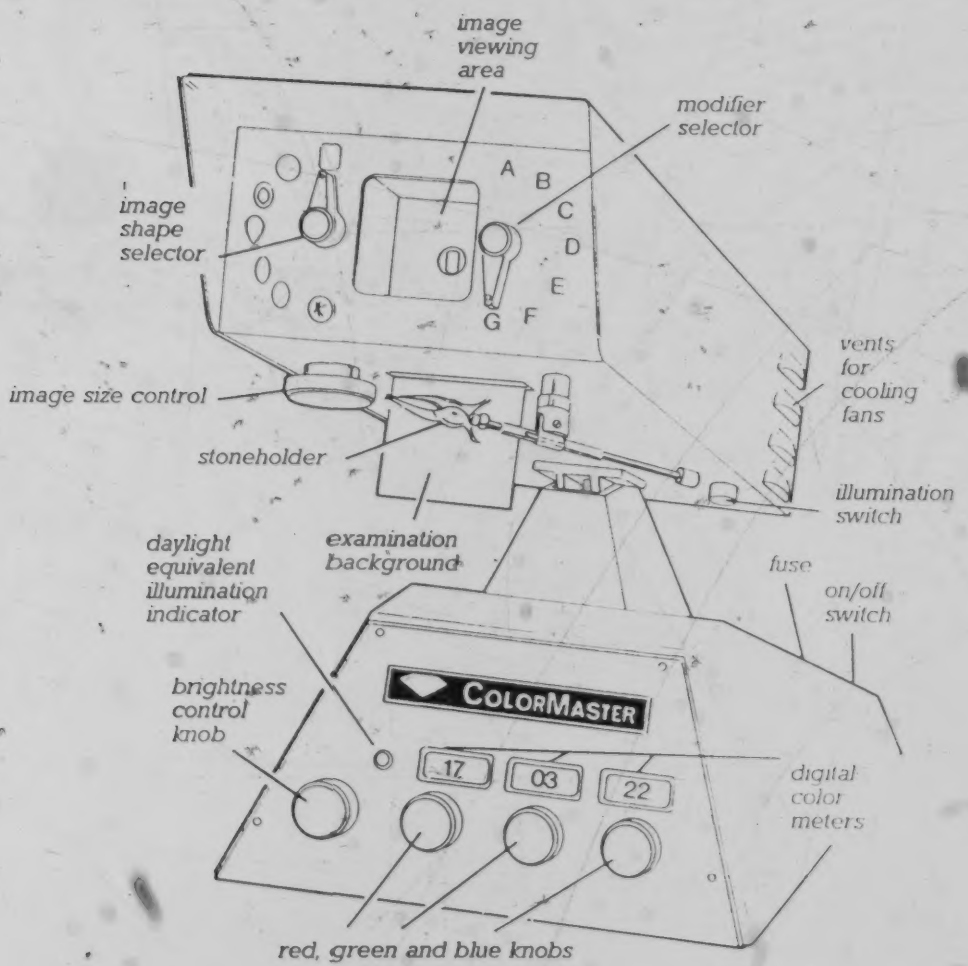

COMPILED DATA
MINERAL DATA
SAMPLE DATA
GENERAL DATA
name, formula, symmetry, classification, proportion sum/base, optical character
composition, cell dimensions and angle, ColorMaster colour, density, hardness, absorption spectra, refractive indicies, optical sign, dispersion, birefringence, transparency, *cut type, *cut weight, *cut dimensions, *collection number, *inclusions, *remarks, *occurrence, *location, *source

Figure 3-3: The Relationship of the four types of data present in the GemIdent data base and their associated parameters.
* = Not part of compiled data

Figure 3-4: Instrument used to obtain ColorMaster notations. (from Color Stone Grading 1988, reproduced with permission of GIA)



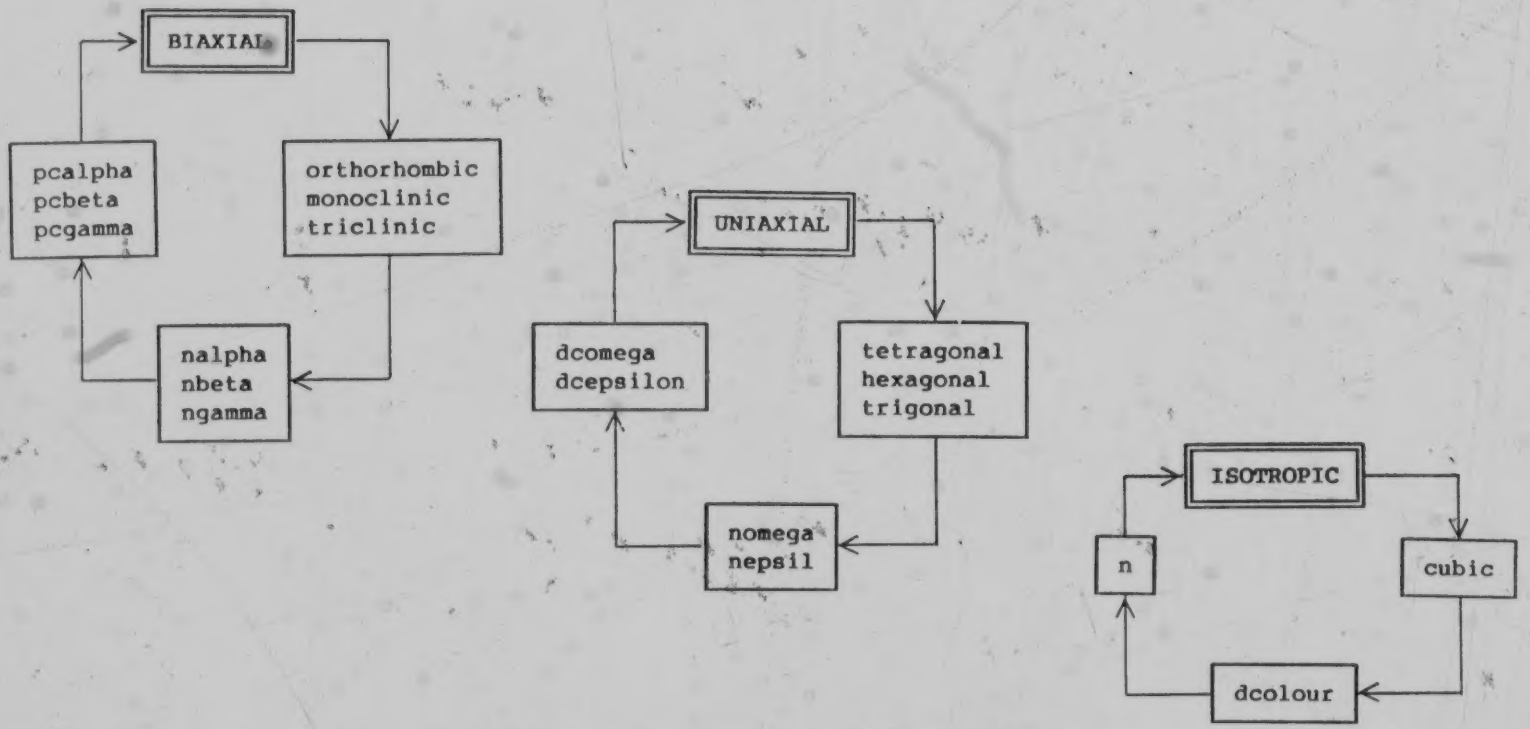


Figure 3-6: Diagrams showing the basis for the compatibility algorithims used in GemIdent.

CHAPTER 4:

APPLICATIONS OF THE GEMIDENT DATA BASE

INTRODUCTION

Gemmology encompasses evaluation of numerical data, qualitative observations, and the examination of the interaction of a large number of properties. In this chapter, the objective is to demonstrate the application of the GemIdent data base in such tasks. The GemIdent data base management program is capable of identifying gems, in addition to selecting, comparing and integrating a wide variety of data. These capabilities have been considered in three sections: identifications, comparisons, and retrieval of gems and gem data. In each section, examples have been chosen to show the relevant procedures. It is important to note that data processing by computers can never replace scientific interpretation of results, it can however, reduce the number of possibilities in a rapid and efficient manner.

IDENTIFICATION OF GEMS

The applications of the GemIdent data base in identification tasks involving physical, optical, and compositional data

are presented in this section. Data for gem minerals to be identified are entered as UNKNOWN DATA and the SAVE command is used to exit the UNKNOWN INPUT request loop. This loop has an associated REQUEST variable. If this variable is activated (i.e., REQUEST=ON), the program will prompt the user for input of each and every possible parameter. Conversly, if the variable is set to OFF, desired inputs may be entered individually.

After the UNKNOWN DATA has been specified, any one of the following commands may be used for identification purposes: IDENTIFY, MATCH, IDENTIFY AND, and MATCH AND. The latter two commands are only of interest when additional data have been entered with the UNKNOWN EDIT command, and after a preliminary reduction in the number of possibilities has been achieved with the MATCH or IDENTIFY commands.

A unique feature of the MinIdent and GemIdent data bases is the calculation of MATCHING INDICES (e.g., TM values), which were discussed in chapter 2. These calculation take into account the degree of mismatch between the UNKNOWN DATA and that available in the data base. Furthermore, a +/- 1% margin of error is assumed in all such calculations.

In this section, the objective is to select examples which demonstrate how the GemIdent data base can be used in identification tasks involving various parameters. The

UNKNOWN DATA used in these examples were primarily obtained from Dana (1911), and Hurlbut and Switzer (1979).

EXAMPLE 1:

A simple approach to identification of unidentified samples is to use the MATCH procedure. This results in a search for gem minerals which match all the UNKNOWN DATA. Where the data in the data base lies outside the range specified for any of the parameters, that gem mineral will be rejected even if some of the other parameters entered were within the range given. Thus, when the MATCH procedure is used, wide ranges can be entered in order to consider all possibilities. In the following example the density, hardness, and symmetry are used to select the gem minerals which have values in the specified range. The optical character (OPC) implied by the symmetry is also automatically considered by the program when SYMMETRY is assigned. The final tabulation contains the mean values for the parameters of the gem minerals which were used for MATCH. The fact that they appear in the tabulation indicates that the range of data available in the data base MATCHed the UNKNOWN DATA, and the TM values reflect the closeness of the match.

```
UNKOWN
DENSITY=2-2.5
MOH=4-5
SYM=ORTHO
Optical-character=Biaxial (from symmetry)
SAVE
MATCH
Scanning within GEMS division
425 minerals examined, 0 ignored, 403 not matched and 7
matched
TABULATE
Defaults are: unk nam tm den moh sym opc
```

Page: 1 of Table

Name	TM	Density	MOH	Symmetry	OpCharact
unidentified sample		2.0 2.5	4.0 5.0	Orthorhombic	Biaxial
MORDENITE	100.0	2.145	4.5	Orthorhombic	Biaxial
NATROAPOPHYLLITE	100.0	2.5	4.75	Orthorhombic	Biaxial
NATROLITE	83.3	2.238	5.25	Orthorhombic	Biaxial
PALYGORSKITE	93.4	2.155	3.25	Multiple	Biaxial
THOMSONITE	83.3	2.341	5.25	Orthorhombic	Biaxial
VARISCITE	99.1	2.585	4.0	Orthorhombic	Biaxial
WAVELLITE	83.3	2.327	3.75	Orthorhombic	Biaxial

In the above tabulation, palygorskite has one of the lowest TM values, because of its lower density and multiple symmetries (monoclinic and orthorhombic) which are due to the different polytyps of the mineral. Cryptocrystalline quartz-impregnated palygorskite has been used for gemmological purposes.

EXAMPLE 2:

In the following example gem minerals with very restricted refractive index readings are considered and only the 1% error margin assigned by the program is taken into account. This error margin is rather large for refractive index measurements, and, in fact if they have been measured accurately it is best to define narrower ranges rather than to allow the program to assume the error. Once again the choice of the parameters used below for the refractive indices implies that the OPC is biaxial, and it is not necessary to enter this parameter separately. This feature

of the program allows the optical character to be considered in the MATCH procedure without having to specify the actual symmetry of the gem under consideration. After a preliminary reduction in the possibilities, the pleochroic scheme is entered with the PLEOCHROISM parameters which allow orientationless colour schemes to be used. This is a useful feature since association of the dichroscopic observation of pleochroic colours with their respective vibration directions can be a rather time consuming process. The logical AND is appended to the IDENTIFY command in order to select the most likely identity from the list previously generated by MATCH. There is insufficient room in the final tabulation of the pleochroic colours for presentation of all colours stored in the COMPILED DATA. Thus only the first colour is shown. Other pleochroic colours may be viewed with the DISPLAY command.

```
UNKNOWN
NALP=1.712
Optical-character=Biaxial (from parameter "n(alpha)"
NBET=1.72
NGAM=1.728
SAVE
MATCH
Scanning within GEMS division
425 minerals examined, 0 ignored, 389 not matched and 12
matched.
UNKNOWN EDIT
PLC=CL,BLUE,BLUE
SAVE
IDENTIFY AND
12 minerals examined, 0 ignored and the top 12 identified.
TABULATE
Defaults are: unk nam tm nal nbet nga plc opc
```

Page: 1 of Table

Name	TM	NAlpha	NBeta	Ngamma	Pleochroic-Colours			OpCharact
unidentified sample		1.695 1.729	1.703 1.737	1.711 1.745	Cl	Bu	Bu	Biaxial
KYANITE	100.0	1.711	1.72	1.726	Pp Bu	Cl	D Bu	Biaxial
SAPPHIRINE	99.9	1.704	1.707	1.71	Pk	L Bu	Bu	Biaxial
THULITE	97.8	1.695	1.699	1.712	L Pk	Cl	L Yl	Biaxial
EPIDOTE	94.6	1.715	1.75	1.751	Cl	Gn Yl	Yl Gn	Biaxial
LEGRANDITE	93.7	1.689	1.7	1.737	Cl	Cl	Cl	Biaxial
ZOISITE	93.6	1.695	1.697	1.701	Bu	Pp	Gn	Biaxial
CLINOZOISITE	93.3	1.71	1.713	1.719				Biaxial
NAMBULITE	93.3	1.706	1.711	1.729				Biaxial
PUMPELLYITE	78.5	1.677	1.68	1.69	Cl	Bu Gn	Cl	Biaxial
ALLANITE-(CE)	33.3	1.781	1.815	1.809	Rd Br	Br Yl	Gn Br	Biaxial
PYROXMANGITE	33.3	1.735	1.738	1.753	Pk Rd	Pk Rd	Pk Rd	Biaxial
RHODONITE	33.3	1.725	1.729	1.737	Yl Rd	L Rd	Yl Rd	Biaxial

In the above tabulation, the minerals with the lowest TM values are opaque and as a result not pleochroic. While it is known that these minerals have high refractive indices, their value is not necessarily significant. They are included in this tabulation because the IDENTIFY algorithm does not reject minerals with empty fields, but assigns appropriately low TM values.

EXAMPLE 3:

Dispersion measurement can have great diagnostic value, although dispersion data has not been reported for many gems. In order to limit the search to those containing such data the MATCHNULL variable is set to NO prior to MATCHing on the basis of dispersion. This variable is associated with the MATCH command and when activated, only gem minerals considered are those for which there are data in all fields

are considered. This is a useful feature, since not all gem minerals have dispersion or spectral data, or are pleochroic. Next, the absorption spectrum and the birefringence of the unidentified gem mineral are used to further reduce the number of possibilities. This is a good example of how standard gemmological measurements may be used effectively in identification of unidentified samples.

```
UNKNOWN
MATCHNULL=NO
DISP=0.17
SAVE
MATCH
Scanning within GEMS division.
425 minerals examined, 0 ignored, 413 not matched and 16
matched.
UNKNOWN EDIT
SPECTR=492,456,436
BIREF=0.011
SAVE
IDENTIFY AND
16 minerals examined, 0 ignored and the top 16 identified.
TABULATE NAME TM BIREF SPECTRA
```

Page: 1 of Table

Name	TM	Birefri	Absorption-Spectra
KUNZITE	87.8	0.015	
LIDDICOATITE	84.5	0.016	
DRAVITE	83.9	0.023	
CORDIERITE	83.3	0.011	426.0,456.0,492.0,535.0,585.0,593.0,645.1.....
SCHORL	81.2	0.032	
ELBAITE	77.2	0.022	
DANBURITE	72.9	0.006	
MARIALITE	49.9	0.013	450.0,488.0,495.5,652.0,663.0.....
HIDDENITE	49.7	0.015	433.0,437.5,620.0,646.0,669.0,686.0,690.5.....
SPODUMENE	49.3	0.018	433.0,437.5,620.0,646.0,669.0,686.0,690.5.....
UVITE	49.1	0.02	430.0,460.0,500.0.....
MEIONITE	33.4	0.033	652.0,663.0.....
CALCITE	33.0	0.181	
TSILAISITE	23.5	0.026	
BUERGERITE	22.4	0.08	
SMITHSONITE	22.2	0.22	

The resulting search included only those gem minerals for which there were dispersion, birefringence and absorption spectra stored in the data base, and the above tabulation is for those that met the requirements of the UNKNOWN DATA.

EXAMPLE 4:

Nondestructive applications of various analytical techniques have made possible the ident fication of gems on the basis of chemical composition. The data may be qualitative or quantitative in nature, and both types of data may be used in the GemIdent data base. Energy dispersive spectra, for example, show the major elements present and this type of qualitative data can be used in conjunction with the MATCH procedure to find compositionally similar gem minerals. In the following example the elements Ca and P were entered as major elements and MATCHed against the entire data base, and the TABULATE command was used to list the formulae and weight percentages of Ca and P for the MATCHed minerals. The LENGTH variable is used prior to the formula parameter in order to increase the default space for listing of formula. Since the number of matched gem minerals is small, a second tabulation is made for their refractive indices and densities which may be used to distinguish among the MATCHed gems.

```
UNKNOWN
W P=MAJOR
W Ca=MAJOR
SAVE
MATCH
Scanning within GEMS division.
425 minerals examined, 0 ignored, 418 not matched and 7
matched.
TABULATE NAME TM LEN 50 FORM W P W Ca
```

Page: 1 of Table

Name	TM	Formula	P	Ca
DICKINSONITE	100.0	(K,Ba)(Na,Ca)5(Mn2+,Fe2+,Mg)14Al(PO4)12(OH,F)2	18.086	4.773
FLUORAPATITE	100.0	Ca5(PO4)3F	18.337	38.994
HERDERITE	100.0	CaBe(PO4)F	18.995	24.58
HURLBUTITE	100.0	CaBe2(PO4)2	24.748	15.884
HYDROXYLAPATITE	100.0	Ca5(PO4)3(OH)	18.113	39.094
HYDROXYLHERDERITE	100.0	CaBe(PO4)OH	19.088	24.591
TRIPHYLITE	99.4	LiFe2+PO4	19.379	1.16

```
TABULATE NAME TM RI DEN
```

Page: 1 of Table

Name	TM	Refractive-Indices			Density
DICKINSONITE	100.0	1.653	1.658	1.667	3.395
FLUORAPATITE	100.0	1.638	1.633		3.225
HERDERITE	100.0	1.581	1.601	1.61	3.02
HURLBUTITE	100.0	1.595	1.601	1.604	2.877
HYDROXYLAPATITE	100.0	1.65	1.648		3.14
HYDROXYLHERDERITE	100.0	1.588	1.608	1.619	2.975
TRIPHYLITE	99.4	1.687	1.688	1.695	3.49

In the above tabulation of refractive index values, the first column corresponds to NOMEG or NEPSIL depending on the

optical character of the gem mineral. Similarly, the second column contains NEPSIL or NBETA values, and the third column contains NGAMMA.

EXAMPLE 5:

To demonstrate the manner in which quantitative compositional data may be used in the GemIdent data base, a chemical analysis of thulite (a pink variety of zoisite) was obtained from Dana (1911, p.514), and first the major elements Si, Al and Ca, were used in a procedure similar to the one above, to reduce the number of possibilities. Next, the weights of all the elements were nulled prior to assignment of actual weight percentages and the IDENTIFY AND command was then used to obtain the 20 most likely candidates.

```
UNKNOWN
W SI=MAJOR
W AL=MAJOR
W Ca=major
SAVE
MATCH
Scanning within GEMS division.
425 minerals examined, 0 ignored, 379 not matched and 46
matched.
UNKNOWN EDIT
W NULL
W SiO2=42.81
W AL2O3=31.14
W CaO=18.73
W H2O=0.64
SAVE
IDENTIFY AND
46 minerals examined 0 ignored and the top 20 identified.
TABULATE
Defaults are: unk nam tm w H w O w Al w Si w Ca w Fe
```

Page: 1 of Table

Name	TM	H	O	Al	Si	Ca	Fe
unidentified sample		0.071	43.618	16.316	19.811	13.252	1.586
		0.072	44.499	16.646	20.211	13.52	1.618
THULITE	98.6	0.114	45.667	14.66	21.502	13.804	1.983
ZOISITE	98.3	0.196	45.51	16.414	19.303	16.334	1.133
BYTOWNITE	96.6	0.04	46.662	17.549	22.276	11.522	0.322
CLINOZOISITE	95.1	0.203	44.888	15.547	18.298	16.592	3.683
MIZZONITE	94.9	0.087	46.561	13.971	22.216	10.602	0.254
EPIDOTE	92.3	0.303	43.175	12.13	17.47	16.159	7.945
LABRADORITE	91.8	0.025	47.164	15.423	24.939	8.559	0.524
PIEMONTITE	91.4	0.182	43.036	11.924	17.188	16.038	5.148
ANORTHITE	88.9	0.016	42.705	20.038	22.13	14.672	0.581
MEIONITE	86.3		43.192	13.389	22.812	10.762	0.119
PYROPE-SPESSARTINE-C	84.3		42.751	11.881	18.703	3.206	2.192
TANZANITE	80.9	0.223	45.424	17.743	18.516	16.84	0.028
MARIALITE	76.4		44.279	11.797	25.877	5.451	0.109
MAGNESIOAXINITE	76.0	0.111	46.351	9.262	20.191	15.012	2.601
UVITE	74.4	0.262	48.819	14.47	16.747	2.692	1.248
DIPYRE	69.7	0.021	45.898	12.513	24.721	7.404	0.089
TSAVORITE	68.8		42.272	11.411	18.354	25.908	0.063
PUMPELLYITE	68.7	0.819	47.065	13.379	17.358	15.627	4.061
GROSSULAR	66.8		42.101	11.297	18.344	25.986	0.869
PREHNITE	65.0	0.488	46.157	13.038	19.733	19.329	0.965

EXAMPLE 6:

The SUBSET facility was discussed in the previous chapter. Its function is to allow a restricted number of gem minerals to be MATCHed or IDENTIFied in a fraction of the normal search time. SUBSETS are LOADed prior to entering the unknown request loop, and as a result searches will include only those gem minerals contained in the SUBSET. In order to switch back to searches involving the entire data base, the SUBSET OFF command is used. Group A and B are two SUBSETS that have been created for the GemIdent data base, They represent some of the most commonly encountered gems in the market place. The following examples demonstrate the application of the SUBSET facility in two separate

identification tasks using various parameters. In both cases, the UNKNOWN DATA were obtained from Hurlbut and Switzer (1979), and the 100% TM values were obtained with the IDENTIFY procedures.

```
SUBSET LOAD GROUP-B
There are 66 minerals in the subset
UNKNOWN
BIREF=0.013
DENSITY=3.27-3.45
PLC=YL,BR YL,GN
Optical-character=Biaxial (from parameter "Pleochroic-
colour(alpha)")
SAVE
IDENTIFY
Using mineral subset with 66 minerals.
66 minerals examined, 0 ignored and the top 20 identified.
TABULATE
Defaults are: unk nam tm bir den plc opc
```

Page: 1 of Table

Name	TM	Birefri	Density	Pleochroic-Colours	OpCharact
unidentified sample		0.013 0.013	3.27 3.45	Yl Br Br Yl Gn	Biaxial
KORNERUPINE	100.0	0.014	3.351	Yl Br Br Gn	Biaxial
ENSTATITE	99.6	0.01	3.276	L Rd Br L Gn Br L Gn	Biaxial
ACTINOLITE	92.5	0.021	3.09	L Yl Gn L Yl Gn L Gn	Biaxial
PUMPELLYITE	91.8	0.013	3.15	Cl Bu Gn Cl	Biaxial
FERROAXINITE	91.3	0.01	3.301		Biaxial
BRONZITE	89.9	0.019	3.326		Biaxial
DUMORTIERITE	85.6	0.026	3.36	D Bu Yl Cl	Biaxial
HEMIMORPHITE	78.4	0.022	3.45		Biaxial
SPHENE	72.4	0.174	3.527	L Yl Br Yl Or Br	Biaxial
SILLIMANITE	70.4	0.018	3.24	L Br Br D Br	Biaxial
EPIDOTE	64.9	0.036	3.415	Cl Gn Yl Yl Gn	Biaxial
FLUORAPATITE	59.6	0.007	3.225		Uniaxial
HYDROXYLAPATITE	52.2	0.002	3.14		Uniaxial
BARITE	40.5	0.012	4.26		Biaxial
GAHNOSPINEL	35.6	0.0	3.967		Isotropic
SPHALERITE	34.1	0.0	4.09		Isotropic
SINHALITE	34.1	0.035	3.483	L Br Gn Br D Br	Biaxial
TREMOLITE	33.3	0.024	2.98	L Yl L Gn	Biaxial
AZURITE	33.3	0.059	3.773	L Bu Gn L Bu Gn L Bu Gn	Biaxial
BENITOITE	33.3	0.044	3.64		Uniaxial

```
SUBSET OFF
No mineral subset is in use.
```

```
SUBSET LOAD GROUP-A
There are 63 minerals in the subset
UNKNOWN
W Si=MAJOR
W Mg=MAJOR
DEN=3.25-3.35
BIREF=0.028
SAVE
IDENTIFY
Using minerals subset with 63 minerals
63 minerals examined, 1 ignored and the top 20 identified.
TABULATE
Defaults are: unk nam tm w Mg w Si bir den
```

Page: 1 of Table

Name	TM	Mg	Si	Birefri	Density
unidentified sample		3.0 100.0	3.0 100.0	0.028 0.028	3.25 3.35
DIOPSIDE	100.0	18.414	25.335	0.03	3.266
DRAVITE	99.2	6.707	16.973	0.023	3.015
IDOCRASE	95.9	1.705	17.077	0.004	3.37
JADEITE	94.6	0.814	27.345	0.016	3.335
ZOISITE	94.5	0.202	19.303	0.007	3.313
NEPHRITE	93.5	13.188	25.083	0.05	3.1
UVITE	89.7	7.72	16.747	0.02	3.14
ELBAITE	79.9	0.054	17.513	0.022	3.093
RHODOCHROSITE	79.9	1.234		0.214	3.62
KUNZITE	79.0	0.012	30.238	0.015	3.1
ZIRCON	77.6	0.162	14.771	0.058	4.685
TANZANITE	74.5	0.042	18.516	0.009	3.355
SPODUMENE	73.5	0.003	30.199	0.018	3.151
SCHORL	72.5	1.197	16.071	0.032	3.195
HIDDENITE	70.8	0.0	30.101	0.015	3.163
CORDIERITE	68.3	4.156	22.838	0.011	2.567
GOSHENITE	67.8	0.0	30.671	0.006	2.725
TSILAISITE	67.7	0.006	16.72	0.026	3.13
PYROPE	67.3	12.138	19.528	0.0	3.74
BERYL	67.3	0.754	30.178	0.008	2.749

```
SUBSET OFF
No mineral subset is in use.
```

When gem minerals are reported as being ignored in a search procedure, it is a refelction of the fact that none of the data specified matched that which was available for that mineral.It must also be noted once again, that the values in the previous tabulation are mean values and that the TM values are a reflection of the degree of mismatch based on the range of data available in the COMPILED RECORD.

COMPARISON OF GEM DATA

Interpretation of any data set requires examination of the interrelation of several factors and their comparison with similar data sets. In GemIdent, the TABULATE command is used to display physical, optical and compositional data, side by side, for comparison purposes. This command consists of three sections: the word tabulate, the parameters to be tabulated, and the minerals for which the tabulations should be made (i.e., tabulate (parameter) of (mineral)). Several examples with different objectives have been chosen to show how this command can be used in conjunction with various parameters.

EXAMPLE 1:

The colour of peridot, which is primarily due to ferrous iron, varies considerably from one sample to the next. The

most desirable green stones are forsteritic in composition, and FeO contents in excess of 15 wt% result in an unattractive brownish-green colouration (Arem 1987). The FeO and MgO weight percentages of peridot samples from some well known localities, together with their ColorMaster colour notation, are presented in the following tabulation. This tabulation may be of particular interest in comparing gemstones from unknown localities, with those having well documented occurrences.

TABULATE NAME REC DATA SAM W MgO W FeO CMNOTATION LEN 26
LOCALITY OF PERIDOT

Page: 1 of Table

Name	Recor	Data	MgO	FeO	CMNotation	Locality
PERIDOT	53	CAVE	49.277	9.413		
	416	SAMP	49.77	8.58		Chavira, Chihuahua, Mexico
	417	SAMP	49.8	8.62		Chavira, Chihuahua, Mexico
	418	SAMP	48.26	11.04		Chavira, Chihuahua, Mexico
	1100	SAMP	50.95	7.95	A 21 57 02	Zebirget, Egypt.
	1101	SAMP	50.44	8.14	B 36 99 01	Burma.
	1102	SAMP	49.51	10.06	A 26 63 03	Arizona, U.S.A.
	1103	SAMP	51.76	6.95	A 38 96 07	Norway.
	1104	SAMP	51.63	6.94	A 37 97 08	Norway.
	1105	SAMP	50.28	8.25		Arizona, U.S.A.
	1106	SAMP	48.89	9.73	B 27 44 01	Arizona, U.S.A.
	1107	SAMP	48.22	9.68	A 18 40 02	Arizona, U.S.A.
	1108	SAMP	49.24	9.22	B 26 50 02	Mexico.
	1109	SAMP	48.9	10.16	B 29 36 01	Burma.
	1110	SAMP	50.71	8.58	B 53 46 01	Burma.
	1111	SAMP	48.25	11.18	C 28 99 00	Arizona, U.S.A.
	1112	SAMP	51.26	7.74	A 29 80 04	Tanzania.

EXAMPLE 2:

Despite the compositional differences between sinhalite and peridot, their appearance and optical properties are similar. For years, sinhalite was assumed to be brownish-green peridot from Burma or Sri Lanka. The higher density

and lower dispersion and most importantly the composition of sinhalite may be used to separate the two gems. The maximum, and minimum values of relevant parameters for these two gem minerals are tabulated below.

TABULATE NAME MIN MAX NALPH NBET NGAM BIREF DISPER MOH OF PERIDOT SINHALITE

Page 1 of Table

Name	NAlpha	NBeta	Ngamma	Birefri	Disp.	MOH
PERIDOT	1.651	1.669	1.684	0.033	0.02	6.5
	1.655	1.673	1.69	0.035	0.02	7.0
SINHALITE	1.61	1.697	1.704	0.029	0.018	6.5
	1.676	1.704	1.712	0.1	0.035	7.0

EXAMPLE 3:

Tourmalines are a complex group of minerals which are commonly fashioned into gemstones. They vary widely in composition, physical and optical properties. The classification TREE for gemmologically significant tourmalines is:

TREE TOURMALINE-GROUP FULL

```
 6:TREE TOURMALINE-GROUP FULL
 1 GEMS top
 2  SILICATES type
 3   CYCLOSILICATES class
 4    TOURMALINE-GROUP group
 5     DRAVITE-SCHORL-SERIES series
 6      DRAVITE species
 7      SCHORL species
 8     DRAVITE-ELBAITE-SERIES series
 9      ELBAITE species
10       TSILAISITE variety
11       INDICOLITE variety
12      DRAVITE species
13     DRAVITE-UVITE-SERIES series
14      UVITE species
15     BUERGERITE species
16     LIDDICOATITE species
```

The standard gemmological properties of these tourmalines are presented in the following tabulation. It is evident that with the exception of schorl and buergerite (both of which are of minor gemmological significance) compositional data must be used for distinguishing between the species.

TABULATE NAME NOMEG NEPSIL DEN DISPER DCOMEG DCEPSIL FSW FLW OF DRAVITE UVITE LIDDICOATITE ELBAITE TSILAISITE BUERGERITE SCHORL

Page: 1 of Table

Name	NOmega	NEpsilo	Density	Disp.	DCOmega	DCEpsil	FSWUV	FLWUV
DRAVITE	1.643	1.62	3.015	0.017	Yl	L Yl	In	In
UVITE	1.642	1.622	3.14	0.017	Yl	L Yl	In	In
LIDDICOATITE	1.637	1.621	3.02	0.017	D Br	L Br	In	In
ELBAITE	1.645	1.623	3.093	0.018	L Pk	D Rd	In	In
TSILAISITE	1.648	1.622	3.13	0.017	D Yl Gn	L Gn		
BUERGERITE	1.735	1.655	3.3	0.017	Yl Br	L Yl		
SCHORL	1.668	1.635	3.195	0.017	Gn Bu	Yl		

In fact, in practical gemmology all these different species are simply regarded as being tourmalines, where their colour and quality are more important than their composition and name. Nevertheless, gem testing laboratories and most gemmological publications make the distinction between the various species. For such tasks it is important to examine the weight percentages of essential elements which are used to distinguish between the species. These are tabulated below:

TABULATE NAME W Mg W Ca W Na W Li W Mn W Fe OF DRAVITE UVITE LIDDICOATITE ELBAITE TSILAISITE BUERGERITE SCHORL

Page: 1 of Table

Name	Mg	Ca	Na	Li	Mn	Fe
DRAVITE	6.707	1.167	1.353		0.025	1.532
UVITE	7.72	2.692	0.677		0.008	1.248
LIDDICOATITE		4.201		1.125		
ELBAITE	0.054	0.245	1.653	0.596	1.119	1.087
TSILAISITE	0.006	0.154	1.836	0.393	6.033	0.031
BUERGERITE	0.078	0.493	2.004		0.101	14.612
SCHORL	1.197	0.075	1.721		0.097	11.117

EXAMPLE 4:

The garnets are another group of minerals with great gemmological significance, and the wide variation in colour and properties necessitate a systematic approach to their identification. Unlike the tourmalines, the classification of garnets used by gemmologists was designed to enable

distinction at series, species or variety level, without the need for compositional data. Their classification was discussed in the previous chapter.

The following is a tabulation of the COMPILED DATA values of the standard gemmological properties of garnets, which are used to distinguish between the various members of this group.

```
TABULATE NAME CMHUE LEN 40 SPECTRA OF GROSSULAR HESSONITE
TSAVORITE ANDRADITE DEMANTOID TOPAZOLITE PYROPE-ALMANDINE-
SERIES RHODOLITE PYROPE CHROME-PYROPE ALMANDINE PYROPE-
SPESSARTINE-SERIES SPESSARTINE PYROPE-SPESSARTINE-CC MALAIA
```

Page: 1 of Table

Name	CMHue	Absorption-Spectra
GROSSULAR	y G	407.0,408.0,409.0,410.0,415.0,420.0,
HESSONITE	Orange	407.0,408.0,420.0,425.0,428.0,429.0,
TSAVORITE	Green	415.0,416.0,420.0,425.0,428.0,460.0,
ANDRADITE	YG	440.0-445.0,447.0,456.0,456.0,475.0,
DEMANTOID	YG	440.0-445.0,447.0,456.0,458.0,475.0,
TOPAZOLITE	o Y	498.0,542.0,617.0,.....
PYROPE-ALMANDINE-SER RHODOLITE	r O st p R	406.0,420.0,423.0,426.0,429.0,456.0, 406.0,408.0,420.0,422.0,428.0,450.0,
PYROPE	RP	406.0,407.0,410.0,420.0,428.0,
CHROME-PYROPE	RO	410.0,420.0,428.0,430.0,440.0-445.0,
ALMANDINE	RO	405.0,406.0,410.0,422.0,423.0,436.0,
SPESSARTINE	Orange	407.0,410.0,420.0,421.0,428.0,430.0,
PYROPE-SPESSARTINE-S	y O	407.0,410.0,421.0,422.0,428.0,429.0,
PYROPE-SPESSARTINE-C	o R	407.0,408.0,410.0,420.0,421.0,429.0,
MALAIA	r O	406.0,408.0,410.0,421.0,428.0,430.0,

In the tabulate command given above the LENGTH parameter is used to specify the width of the field for the next parameter which immediately follows. When the LENGTH parameter is not specified the default value is used. The

default tabulation for colour includes only one COMPILED HUE, and the remainder may be viewed with the DISPLAY command. Table 3-2a contains the full name for the above abbreviations used for ColorMaster HUEs.

Example 5:

The scapolites are another interesting group of gems. The linear relationships among the chemical composition, the mean refractive index and the birefringence in this group was verified by Shaw (1960). In gemmological terms, this allows correct application of scapolite names by measuring only the refractive index. The range of refractive indices for the scapolites in the marialite-meionite series are tabulated below.

TABULATE NAME MIN MAX NOMEG NEPSIL BIREF OF MARIALITE - DIPYRE MIZZONITE MEIONITE

Page: 1 of Table

Name		NOmega	NEpsilo	Birefri
MARIALITE	MIN	1.539	1.531	0.009
	MAX	1.587	1.553	0.056
DIPYRE		1.56	1.544	0.016
		1.569	1.551	0.018
MIZZONITE		1.57	1.549	0.021
		1.587	1.557	0.032
MEIONITE		1.587	1.554	0.028
		1.6	1.562	0.044

The TABULATE command allows easy access to a large number of properties. Similar approaches may be used to list desired properties for any numbers of gem minerals. In the next section, alternative procedures for retrieving data are outlined.

RETRIEVAL OF GEM DATA

GemIdent is the first gemmological data base which allows retrieval of gem minerals based on physical, optical and/or compositional data. Retrieval of gem data from the GemIdent data base can be based on the name, record number or collection number, and gemmological properties.

NAMES AND RECORD NUMBERS

Gem mineral names contained in the GemIdent data base may be accessed through the MRECORDS (MREC) command, and the associated data may be obtained with the DISPLAY command. In the following example, the MREC command has been used to obtain the names of all gem minerals beginning with "di".

MREC DI

#	Rec#	#Sa	#Ge	Name
1	183	0	2	DIAMOND
2	109	11	5	DIASPORE
3	116	0	2	DICKINSONITE
4	117	0	1	DICKINSONITE-ARROJADITE-SERIES
5	112	3	3	DIOPSIDE
6	111	0	1	DIOPSIDE-HEDENBERGITE-SERIES
7	406	3	3	DIOPTASE
8	108	3	1	DIPYRE

SAMPLE and GENERAL RECORD NUMBERS may be retrieved via the SREC and GREC commands respectively. This command requires the name of the gem mineral for which the records are to be retrieved. The resulting tabulation contains the SAMPLE/GENERAL RECORD NUMBERS as well as the SOURCE reference from which they were obtained. The GREC command is used to retrieve the GENERAL RECORD NUMBER for petalite, and the SREC command is used to retrieve the SAMPLE RECORD NUMBERS for enstatite.

GREC PETALITE

#	Rec#	Source
1	235	Z. Dt. Gemmol. Ges. v.20, p.172-174
2	236	J. Gemm. v.13, p.95
3	237	Revue de Gemmol. v.55, p.14-16
4	262	Arem (1987) Encyl. Gems
5	545	Webster (1983)
6	811	Hurlbut & Klein (1977) Manual of Mineralogy

SREC ENSTATITE

#	Rec#	Source
1]	173	J. Gemm. v.16, p.236-238
2]	174	Deer et al. (1962) v.3, p.88
3]	175	Z. Dt. Gemmol. Ges. v.23, p.192-194
4]	176	Z. Dt. Gemmol. Ges. v.26, p.206
5]	177	J. Gemm. v.18, p.213-216
6]	178	J. Gemm. v.18, p.419-425
7]	180	J. Gemm. v.21, p.92-94
8]	181	Gems & Gemol. v.15, p.118-122
9]	182	Gems & Gemol. v.15, p.118-122
10]	183	Gems & Gemol. v.15, p.118-122
11]	184	Gems & Gemol. v.15, p.118-122
12]	185	Gems & Gemol. v.15, p.118-122
13]	186	Gems & Gemol. v.15, p.118-122
14]	206	J. Gemm. v.18, p.419-425
15]	419	J. Gemm. v.15, p.236-238
16]	420	J. Gemm. v.15, p.236-238

The data contained in any of the above records may be viewed with the DISPLAY command. Examples of such DISPLAYS were presented in the previous chapter.

Data for gems belonging to particular collections may be accessed via the COLLECTION-NUMBER-RECORD (CNREC) command. The entire collection number (e.g., USNM-2082), or the first few characters may be used to obtain the SAMPLE RECORD NUMBERS which contain the pertinent data. The collection numbers of gems from the United States National Museum are retrieved with the CNREC command. Any one of these SAMPLE RECORDS may be viewed with the DISPLAY command.

CNREC US

#	Collection Number	REC#	Name
1	USNM-103262	832	WITHERITE
2	USNM-10734	13	AMBLYGONITE
3	USNM-133772-A	518	SAPPHIRINE
4	USNM-1396	1094	GEORGIA
5	USNM-141247	152	DUMORTIERITE
6	USNM-141800	154	DUMORTIERITE
7	USNM-142506	423	PAINITE
8	USNM-2082	1095	MASSACHUSETTES
9	USNM-5841	14	AMBLYGONITE
10	USNM-82452	438	PECTOLITE
11	USNM-95775	153	DUMORTIERITE
12	USNM-97256	653	STRONTIANITE
13	USNM-B12207	274	JEREMEJEVITE
14	USNM-R12631	750	BUERGERITE
15	USNM-R17011	751	ELBAITE
16	USNM-R9952	225	HAMBERGITE

GEMMOLOGICAL PROPERTIES

Retrieval of gems based on gemmological properties involves specification of the criteria in terms of UNKNOWN DATA, followed by the MATCH and/or MATCH AND commands. The MATCH command searches the entire data base, and the MATCH AND command searches the previously matched minerals. To view the selected minerals, the TABULATE command is issued without any modifiers since the default parameters consist of those which were used as UNKNOWN DATA. The versatility of the GemIdent data base with respect to retrievals based on physical, optical, and/or compositional properties has been demonstrated in this section with several examples.

Physical and structural properties that may be retrieved are: MOHS, DENSITY, CELL DIMENSIONS and ANGLES, OPTICAL CHARACTER/SIGN, SYMMETRY, INCLUSIONS, OCCURRENCE, and LOCALITY. The GemIdent data base contains 425 MINERAL RECORDS and it may be of interest to know how many gems at the species and variety level are faceted into gemstones more for the sake of curiosity than for wear. This can be accomplished by considering and assuming that a hardness range 1-5 would renders them impractical for wear. To limit the search to the species and variety level, the LCUTOFF variable is used. This variable allows specification of a classification level whereby all gem minerals higher or equal to that level of the hierarchy will be ignored in the search/match algorithms. Thus, to match species and varieties, the LCUTOFF variable is set to the SERIES level of the classification. In fact, this LCUTOFF level is maintained for most searches, however it should be noted that for cases where unsatisfactory search/match results are obtained, it is recommended that the variable be set to a higher level of classification. To select those gem minerals which also have low densities (i.e., <2.0 gm/cc), the UNKNOWN EDIT command is used to specify the density, and this if followed by the MATCH AND command.

```
UNKNOWN
LCUTOFF=SERIES
MOH=1-5
SAVE
MATCH
Scanning within GEMS division.
425 minerals examined, 0 ignored, 275 not matched and 150
matched.
```

```
UNKNOWN EDIT
DEN=1-2
SAVE
MATCH AND
150 minerals examined, 0 ignored, 143 not matched and 7
matched.
TABULATE
Defaults are: unk nam tm den moh
```

Page: 1 of Table

Name	TM	Density	MOH
unidentified sample		1.0 2.0	1.0 5.0
ETTRINGITE	100.0	1.76	2.25
GAYLUSSITE	100.0	1.995	2.75
INDERITE	100.0	1.8	2.5
KURNAKOVITE	100.0	1.861	2.5
MELLITE	100.0	1.625	2.25
THAUMASITE	100.0	1.91	3.5
ULEXITE	100.0	1.955	1.75

It is possible to combine searches to include any number of parameters. In the following example, the objective has been to obtain a list of monoclinic gem minerals whose beta cell angle is 90 degrees. This task requires that all biaxial minerals be retrieved with the MATCH command. From this group, the monoclinic gem minerals will be selected using MATCH AND. The list will be further reduced by another MATCH AND command in order to obtain those with the specified beta angle.

```
UNKNOWN
OPC=BIAXIAL
SAVE
MATCH
Scanning within GEMS division.
425 minerals examined, 0 ignored, 262 not matched and 163
matched.
```

```
UNKNOWN EDIT
SYM=MONOCLINIC
SAVE
MATCH AND
163 minerals examined, 0 ignored, 85 not matched and 78
matched.
UNKNOWN EDIT
BETA=90
SAVE
MATCH AND
78 minerals examined, 0 ignored, 63 not matched and 15
matched.
TABULATE
Defaults are: unk nam tm bet sym opc
```

Page: 1 of Table

Name	TM	Beta	Symmetry	OpCharact
unidentified sample		89.1 90.9	Monoclinic	Biaxial
BERYLLONITE	100.0	90.0	Monoclinic	Biaxial
CATAPLEIITE	100.0	90.41	Monoclinic	Biaxial
CRYOLITE	100.0	90.278	Monoclinic	Biaxial
DATOLITE	100.0	90.408	Monoclinic	Biaxial
GADOLINITE-(CE)	100.0	90.13	Monoclinic	Biaxial
HERDERITE	100.0	90.1	Monoclinic	Biaxial
HUEBNERITE	100.0	90.883	Monoclinic	Biaxial
HURLBUTITE	100.0	90.5	Monoclinic	Biaxial
HYDROXYLHERDERITE	100.0	90.02	Monoclinic	Biaxial
LIZARDITE	100.0	90.0	Monoclinic	Biaxial
MESOLITE	100.0	90.0	Monoclinic	Biaxial
PYRRHOTITE	100.0	90.083	Multiple	Multiple
SAMARSKITE-(Y)	94.9	91.9	Monoclinic	Biaxial
SCOLECITE	83.7	90.65	Monoclinic	Biaxial
STAUROLITE	100.0	90.0	Monoclinic	Biaxial

Once again the beta values in the tabulation are mean values, and the TM values are a reflection of how Retrieval of gems based on INCLUSIONS, OCCURRENCE, and LOCALITY involve string searches which are conducted by the MATCH procedure. Up to 20 characters may be used in such searches and it is recommended that the simplest form of

word (e.g., basalt rather than basaltic) be used rather than a combination of words (e.g., basaltic dyke), since the possible variations make incomplete overlap inevitable. A string search has been conducted for Bolivia, to obtain the names of gems minerals available from this locality. The default tabulation for such string searches includes all SAMPLE and GENERAL RECORDS of the MATCHed minerals. Due to space limitations, the final tabulation contains the only names and formulae of gem minerals found in Bolivia, the locality information being omitted.

```
UNKNOWN
LOCALITY=BOLIVIA
SAVE
MATCH
Scanning within GEMS division.
425 minerals examined, 0 ignored, 414 not matched and 11
matched.
TABULATE NAME FORMULA
```

Page: 1 of Table

Name	Formula
AUGELITE	Al2(PO4)(OH)3
CASSITERITE	SnO2
CERULEITE	Cu2Al7(AsO4)(OH)13:12H2O
CREEDITE	Ca3Al2(SO4)(F,OH)10:2H2O
CUPRITE	Cu2O
MARCASITE	FeS2
MONAZITE-(CE)	(Ce,La,Nd,Th)PO4
PHOSPHOPHYLLITE	Zn2(Fe,Mn)(PO4)2:4H2O
PYRARGYRITE	Ag3SbS3
VIVIANITE	Fe2+3(PO4)2:8H2O
WAVELLITE	Al3(PO4)2(OH,F)3:5H2O

Similar searches may be done for the OCCURRENCE, INCLUSIONS, and REMARKS fields.

The optical properties that may be used to retrieve data are: TRANSPARENCY, REFRACTIVE INDICES, BIREFRINGENCE, DISPERSION, PLEOCHROIC-COLOUR, DICHROIC-COLOUR, FLUORESCENCE, COLORMASTER HUE (CMHUE), and ABSORPTION SPECTRA.

The practical range of refractive index measurement using gemmological refractometers includes all values below 1.80. Thus other means of identification are required for gems with high refractive indices. In the following example, tetragonal gem minerals whose refractive indices are greater than 1.8 are retrieved. This objective requires specification of orientationless refractive indices using the REFRACTIVE-INDEX (RI) parameter, with subsequent selection of tetragonal gems using the MATCH AND command. It is important to note that once the symmetry is specified, the OPTICAL-CHARACTER (opc) compatible with that symmetry is set automatically. To avoid matching against symmetry and/or optical-character, OPC is nulled, so as to retrieve only the tetragonal gem minerals.

```
UNKNOWN
RI=1.8
SAVE
MATCH
Scanning within GEMS division.
425 minerals examined, 0 ignored, 402 not matched and 23
matched.
UNKNOWN EDIT
SYM=TETRAGONAL
Optical-character=Uniaxial (from symmetry)
OPC=NULL
```

```
SAVE
MATCH AND
23 minerals examined, 0 ignored, 22 not matched and 1
matched.
TABULATE UNK NAME REC DATA TM MIN MAX AVE RFR SYM OPC
```

Page: 1 of Table

Name	Recor	Data	TM	Refractive-Indices		Symmetry	OpCharact
unidentified sample		UMIN		1.782		Tetragonal	Uniaxial
		UMAX		1.818			
ZIRCON	397	CMIN	89.8	1.78	1.79	Tetragonal	Uniaxial
		CAVE		1.938	1.996		
		CMAX		1.95	2.01		

The tabulation of the minimum, maximum, and average COMPILED values for zircon show that, in fact, the range of refractive indices match the UNKNOWN DATA.

The next example outlines the procedure for obtaining gem minerals with similar pleochroic schemes (PCALPHA=colourless, PCBETA=red, PCGAMMA=yellow).

```
UNKNOWN
MATCHNULL=NO
PCALP=CL
Optical-character=Biaxial (from parameter "Pleochroic-
colour(alpha)")
PCBET=RED
PCGAM=YL
SAVE
MATCH
Scanning within GEMS division.
425 minerals examined, 0 ignored, 420 not matched and 5
matched.
TABULATE
Defaults are: unk nam tm pca pcb pcg opc
```

Page: 1 of Table

Name	TM	PCAlpha	PCBeta	PCGamma	OpCharact
unidentified sample		Cl		Yl	Biaxial
HUREAULITE	68.8	Cl	L Rd	Rd Yl	Biaxial
KORNERUPINE	52.2	Yl Br	Br	Gn	Biaxial
MONAZITE-(CE)	68.8	Cl	Rd Or	Yl	Biaxial
STAUROLITE	100.0	Cl	Yl	Yl	Biaxial
TOPAZ	100.0	Yl	Yl	Yl	Biaxial

The retrieval of gems based on compositional criteria is perhaps one of the most attractive aspects of the data base, especially in the light of the application of nondestructive analytical techniques for gem characterisation. Light elements with atomic numbers less than Na are difficult to analyse with most microbeam techniques, and, in fact, partial analyses are acceptable in such cases. The procedure for retrieving gem minerals containing the light elements Li, Be and B as essential/major constituents (e.g., >3wt%) is given below.

```
UNKNOWN
W Li=MAJOR
SAVE
MATCH
Scanning within GEMS division.
425 minerals examined, 0 ignored, 420 not matched and 5
matched.
TABULATE NAME FORMULA W Li
```

Page: 1 of Table

Name	Formula	Li
AMBLYGONITE	(Li,Na)Al(PO4)(F,OH)	3.089
HIDDENITE	LiAlSi2O6	3.073
KUNZITE	LiAlSi2O6	3.49
SPODUMENE	LiAlSi2O6	3.172
TRIPHYLITE	LiFe2+PO4	3.912

```
UNKNOWN
W Be=MAJOR
SAVE
MATCH
Scanning within GEMS division.
425 minerals examined, 0 ignored, 405 not mactched and 20
matched.
TABULATE NAME FORMULA W Be
```

Page: 1 of Table

Name	Formula	Be
ALEXANDRITE	BeAl2O4	7.206
AQUAMARINE	Be3Al2Si6O18	4.299
BERYL	Be3Al2Si6O18	4.505
BERYLLONITE	NaBePO4	7.019
BIXBITE	Be3Al2Si6O18	5.03
CHRYSOBERYL	BeAl2O4	7.17
EMERALD	Be3Al2Si6O18	4.619
EUCLASE	BeAlSiO4	6.576
GADOLINITE-(CE)	(Ce,La,Nd,Y)2Fe2+Be2Si2O10	3.34
GOSHENITE	Be3Al2Si6O18	4.853
HAMBERGITE	Be2BO3(OH)	19.187
HELIODOR	Be3Al2Si6O18	5.03
HERDERITE	CaBe(PO4)F	5.527
HURLBUTITE	CaBe2(PO4)2	7.471
HYDROXYLHERDERITE	CaBe(PO4)OH	5.581
MELIPHANITE	(Ca,Na)2Be(Si,Al)2(O,OH,F)7	3.881
MORGANITE	Be3Al2Si6O18	4.378
PHENAKITE	Be2SiO4	15.178
RHODIZITE	(Cs,K)Al4Be4(B,Be)12O28	8.909
VAYRYNENITE	MnBe(PO4)(OH,F)	4.582

```
UNKNOWN
W B=MAJOR
SAVE
MATCH
Scanning within GEMS division.
425 minerals examined, 0 ignored, 402 not matched and 23
matched.
TABULATE NAME FORMULA W B
```

Page: 1 of Table

Name	Formula	B
BORACITE	Mg3B7013Cl	18.703
BUERGERITE	NaFe3+3Al6B3Si6027(O,OH)3(OH,F)	3.227
CHAMBERSITE	Mn3B7013Cl	15.506
COLEMANITE	Ca2B6011:5H20	15.658
DANBURITE	CaB2(Si04)2	8.186
DATOLITE	CaBSi04(OH)	6.515
DRAVITE	NaMg3Al6[B03]3Si6018[OH]4	3.339
ELBAITE	Na(Al,Li)3Al6B3Si6027(O,OH)3(OH,	3.287
GRANDIDIERITE	(Mg,Fe2+)Al3(B04)(Si04)O	2.636
HAMBERGITE	Be2B03(OH)	11.274
HOWLITE	Ca2B5Si09(OH)5	13.966
INDERITE	MgB303(OH)5:5H20	11.591
INDICOLITE	Na(Li,Al)3Al6(B03)3Si6018(OH)4	3.22
JEREMEJEVITE	Al6B5015(OH,F)3	10.523
KURNAKOVITE	MgB303(OH)5:5H20	11.523
LIDDICOATITE	Ca(Li,Al)3Al6(B03)3Si6018(O,OH,	3.399
RHODIZITE	(Ca,K)Al4Be4(B,Be)12028	15.066
SCHORL	NaFe2+3Al6B3Si6027(O,OH)3(OH,F)	3.202
SINHALITE	MgAlB04	8.045
TSILAISITE	NaMn3Al6B3Si6027(OH)4	3.284
TUGTUPITE	Na4AlB2Si4012Cl	33.106
ULEXITE	NaCaB506(OH)6:5H20	13.474
UVITE	CaMg3Al5MgB3Si6027(O,OH)3(OH,F)	3.356

More important, perhaps, is the capability for retrieving compositionally similar species and varieties whose physical and/or optical properties are within a specified range. To demonstrate this feature, the procedure for retrieval of cubic silicate gem minerals is shown.

```
UNKNOWN
CLASS OF SILICATES
SYM=CUBIC
Optical-character=Isotropic (from symmetry)
SAVE
MATCH
216 minerals within classification.
216 minerals examined, 0 ignored, 196 not matched and 20
matched.
TABULATE FORM SYM
```

Page: 1 of Table

Formula	Symmetry
Fe3Al2Si3O12	Cubic
NaAlSi2O6:H2O	Cubic
Ca3Fe2Si3O12	Cubic
Mg3Al2Si3O12	Cubic
Ca3Fe2Si3O12	Cubic
Ca3Al2Si3O12	Cubic
Na8Al6Si6O24Cl2	Cubic
(Na,Ca)4-8Al6Si6(O,S)24(SO4,	Cubic
Ca3Al2Si3O12	Cubic
(Na,Ca)7-8(Al,Si)12(O,S)24([SO4],	Cubic
(Mg,Mn)3Al2Si3O12	Cubic
(Cs,Na)2Al2Si4O12:H2O	Cubic
Mg3Al2Si3O12	Cubic
(Mg,Mn)3Al2Si3O12	Cubic
(Mg,Fe)3Al2Si3O12	Cubic
Na8Al6Si6O24Cl2	Cubic
Mn3Al2Si3O12	Cubic
Ca3Fe2Si3O12	Cubic
Ca3Al2Si3O12	Cubic
Al13Si5O20(OH,F)18Cl	Cubic

Calculation of composition from the formula can be a time consuming task. GemIdent can calculate the theoretical weight percentages of elements from the formula. This has been demonstrated with the formula of the gem mineral dumortierite.

```
UNKNOWN
FORMULA=Al7(BO3)(SiO4)3O3
Weight B =  1.871-  1.909 (average=  1.890).
Weight O = 49.850- 50.858 (average= 50.354).
Weight Al= 32.693- 33.354 (average= 33.023).
Weight Si= 14.585- 14.880 (average= 14.732).
SAVE
```

In this calculation the actual value is given in parentheses. The apparent range produced by a "fixed" formula, such as the one above is based an arbitrary +\- 1 % calculation from the actual value.

CHAPTER 5:

THE NONDESTRUCTIVE APPLICATION OF THE ELECTRON MICROPROBE TO GEM CHARACTERISATION AND IDENTIFICATION

INTRODUCTION

Nondestructive gemmological applications of the electron microprobe in gem identification and characterisation were discussed in chapter 1. Energy and wavelength dispersive analyses of gem materials are still relatively rare in the gemmological literature, and the full potential of the microprobe has not been realised in gemmology. This became evident in the early stages of data gathering for the GemIdent data base. As as result, many of the gaps in the literature have been supplemented, in the data base with mineralogical data. The primary objective in this study has been to contribute quantitative microprobe analyses for a variety of gem minerals to the existing literature, and to demonstrate how microprobe data may be used for identification of gems with GemIdent. Faceted gemstones and gem quality fragments were obtained on loan from the Gemological Association of America (GIA), and an attempt was made to select some of the lesser known gem species and varieties for which there was little compositional data available.

Wavelength dispersive analyses were collected for: andalusite, chrome-diopside, chrysoberyl, cordierite, danburite, grossular, kunzite, prehnite, sinhalite, sphalerite, tanzanite, willemite, and zoisite. In addition, the trace element contents of 8 natural rubies from various localities were also obtained with wavelength dispersive techniques, since very few quantitative microprobe analyses were available in the literature.

In the following section, a description of the technique which was developed for mounting of gem specimens is described. This is followed by an outline of the experimental procedure and presentation of results. In the final section, one of the microprobe analyses has been selected for a demonstration of how the GemIdent data base could have been used if the specimen had been an unidentified sample.

SAMPLE PREPARATION

The limiting factor in preparing faceted gems for electron microprobe analysis is that while fulfilling several basic criteria, the technique must remain nondestructive. A flat, polished and electrically conductive surface, preferably oriented perpendicular to the beam, is required in order to obtain quantitative microprobe analysis. The mounting medium must be able to support different sized gems must not give

rise to out-gasing, must be completely removable, and preferably electrically conductive. Two different mounting media met the above requirements. The first was apiezon putty; although nonconductive, it is stable under vacuum conditions up to 10^{-6} torr and easily removable even if the gems remain in the medium for long periods of time. The second is a conductive silver epoxy which is routinely used for samples under investigation with a scanning electron microscope. This medium is also stable under vacuum up to 10^{-6} torr, and may be removed with acetone. The advantage of the epoxy lies in its conductivity, however it requires more than 24 hours to dry. Soaking samples in acetone is effective in removing the epoxy, and does not harm most gems. However, it cannot be used for oiled and/or dyed gems.

In light of the above possibilities and limitations, the apiezon putty was selected as a mounting medium .To compensate for its nonconductivity, conductive silver paint was employed to avoid charge build up. Gemstones were cleaned thoroughly with acetone and distilled water, wiped dry with a lint-free tissue, and placed table down on a clean surface. Depending on the dimensions of samples, several gems can usually be mounted into an open-ended plastic cylinder containing apiezon putty, by distancing the gems appropriately and pressing the putty around the gems. This open-ended cylinder must be of a size which can be accommodated by the sample holder of an electron microprobe.

The entire surface is then coated with a very thin and uniform layer of carbon by vacuum evaporation, in order to provide for conductivity on the surface of the gems. A strip of conductive silver paint is applied with great care, from the outer edge of each gemstone out onto the apiezon putty and to the edge of the plastic sample holder. In plate 5-1 photographs of such cylindrical mounts are shown.

This mounting technique was tested for adequate electrical conductivity, by taking X-ray photon counts of aluminium Kα on a ruby sample at a location close to the silver paint where conductivity was bound to be good, and another in the centre of the gem. The aluminium Kα counts from these two locations were within the statistical error range.

Several months after having developed this mounting techniques, a paper was found in which a similar mounting technique had been described (Dunn 1977a). This paper had essentially gone unnoticed. Microanalytical techniques have also been explored by researchers at the GIA using orthodontal resin as a mounting medium. The limitations of this medium for mounting gems for microanalysis were discussed by Stockton (1986).

EXPERIMENTAL

An Applied Research Laboratory SEMQ microprobe, and a JEOL Superprobe 733 microprobe, equipped with four crystal spectrometers, each were used for wavelength dispersive analysis (WDA) of faceted gem minerals and some gem quality fragments. The ARL SEMQ microprobe was used only for the trace element analyses of rubies from the GIA collection. All other analyses were obtained with the JEOL 733 microprobe.

A 15 kV accelerating voltage was used for all analyses. This value was a compromise between reducing counting times with higher voltages, and reducing matrix corrections at lower voltages. At this accelerating voltage the requirement for the critical excitation energy of the elements of interest were met. In addition, the energy of incident electrons resulted in an electron penetration and spread which did not severely increase absorption corrections. Probe currents of 5-10 nA were used and no problems with volatilization or heating of the sample at point of impact were encountered.

The cathodoluminescence of some samples at the point of electron beam impact facilitated the location of points for analysis. In other cases, the simultaneous viewing and optical focussing capabilities of the microprobes were used to locate points for analysis. The position of the beam was

changed approximately every 80 seconds in order to avoid carbon contamination and sample damage.

A combination of compound and pure element standards was used in the study. Chemically simple standards or ones with well known compositions which had a greater weight percentage of an element than that expected in the samples to be analysed were chosen. The standards used for the elements analysed, are presented in the following tabulations, together with a summary of all operating conditions.

Table 5-1 summarises the operating conditions of the ARL SEMQ microprobe used in the trace element study of rubies. Synthetic Bayer corundum was used to determine background measurements at peak positions for elements that it did not contain but that were of interest in the sample rubies. Since the elements were present in trace amounts, it was critical to obtain accurate background measurements. The upper and lower background positions of the Al Kα analytical line were used to determine the continuum level for both sample and standards. The choice of a compositionally similar standard material to obtain background measurements at spectrometer peak positions, prevented errors arising due

to differences in absorption. The same analytical conditions were used for both standards and samples.

Also of interest were the variations of the trace elements in a given sample. Thus, a "paired count" technique was employed, since this method can demonstrate inhomogeneity more clearly than a single count at different points in a sample. The paired count technique utilized two 40 seconds counting periods at each location. Comparison of two locations on the basis of a single count will reveal compositional variations only when the counts differ by an amount exceeding statistical probability.

Table 5-2 is a summary of the operating conditions of the JEOL 733 microprobe which was used to collect data on all other samples. Stability of the instrument was monitored with calibration standards which were run at the beginning and end of each analytical session. This procedure allowed for monitoring of drift in the crystal spectrometers. In addition, a Faraday cup measurement was taken before the analysis of standards at the beginning and end of each analytical run.

RESULTS

Trace element data from ruby samples obtained with the ARL SEMQ microprobe were processed with EDATA2 (Smith and Gold, 1979). EDATA2 is a FORTRAN IV data reduction program which employs ZAF corrections in addition to provisions for instrumental drift, variations in probe current, and electronic noise. The wavelength dispersive results collected with the JEOL 733 microprobe were processed with Tracor Northern software available at the University of Dalhousie, in Halifax.

In the trace element study of rubies, the errors in the microprobe analyses were estimated on the basis of counting statistics according to the procedures presented in Jenkins and De Vries (1969). The calculations are only an approximation since there are uncertainties in the accuracy of the peak:background ratio for these trace elements, where this ratio is low. Such error calculations were not attempted for the other analyses due to the uncertainties which are inherent to collection of electron microprobe data. Based on the past performance characteristics of the JEOL 733 microprobe and under the specified operating conditions, the estimated error in trace element content is 0.05 %, and for major elements this error is 1.5 - 2.0 % (both are for the 99% confidence level).

Uncertainties in microprobe analysis include accuracy of the peak:background ratio, the chemical homogeneity and elemental concentrations in standards, in addition to those due to ZAF corrections. Factors such as thickness of carbon coating of sample and standards, sample contamination, sample damage, and surface characteristics of samples can also contribute to errors. Given these uncertainties, it is difficult to estimate the size of errors present in microprobe analyses.

All microprobe data with the exception of those for sphalerite, are given in weight percentages of oxides. FeO represents total Fe content. The weight % oxides of BeO, Li_2O, B_2O_3, and H_2O were taken as the difference of the totals from 100 %.

Wavelength dispersive analyses of rubies are presented in table 5-3, and the average error calculation (at the 99% confidence level) for each of the trace elements analysed are given in table 5-4. Since corundum is essentially stoichiometric, the aluminum content was calculated by difference. All Na concentrations calculated by the EDATA2 program were assigned null values due to the fact that the data base did not contain data on the standard used for Na (tugtupite CCNM # 311). However, the raw data indicated that all samples except for samples 12427B and 11432 contained trace quantities of sodium. The weight percentages of the

trace elements collected in this study are compared to those available in the GemIdent data base (table 5-5). These ruby analyses were subsequently added to the GemIdent data base.

Microprobe analyses for andalusite, diopside, chrysoberyl, cordierite, danburite, sinhalite, grossular, kunzite, prehnite, sphalerite, tanzanite, zoisite, and willemite are presented in tables 5-6 to 5-16 respectively. Visual comparison of these analyses with those in the COMPILED RECORDS of the GemIdent data base indicated that all analyses obtained in this study are comparable to previously determined data in the literature.

The danburite microprobe analysis has been chosen to illustrate how the GemIdent data base could have been used if any of the above gems had been unidentified samples. The procedures and results are presented in table 5-17. Since the number of minerals which matched the criteria specified is small, it is not necessary to follow up with an IDENTIFY AND command. From the tabulations of matched minerals it is evident that only danburite has weight percentages of major elements similar to those obtained in this study.

Table 5-1: Summary of the analytical conditions of the electron microprobe analyses of the ruby samples. Analyses collected with WDA techniques on the ARL SEMQ microprobe at the Microprobe Laboratory at the University of Alberta. (CCNM are U. of A. computer code numbers).

Accelerating voltage:	15 kV	
Probe current :	5 nA	
Beam :	defocussed 10 μbeam	
Analysing crystals :	LIF: Ti, V, Cr, Mn, Fe Co, Ni	
	TAP: Al, Na, Mg	
	PET: Si	
Counting times :	ten counting periods of 40 seconds each for both peak and background measurements	
Number of analysis points :	2 "paired counts" per sample (see text)	
Analytical Standards:	Si: albite	(CCNM #29)
	Al: Bayer - corundum	(CCNM #76)
	Co: Co-metal	(CCNM #82)
	Cr: chomite	(CCNM #62)
	Fe: hematite	(CCNM #137)
	Mg: periclase	(CCNM #238)
	Mn: MnO_2	(CCNM #194)
	Ni: Ni-sheet	(CCNM #201)
	Ti: rutile	(CCNM #271)
	Na: tugtupite	(CCNM #311)
	V : V-metal	(CCNM #327)

Table 5-2: Summary of the analytical conditions of the electron microprobe analyses of various faceted gems. Analyses collected with WDA techniques on the JEOL Superprobe 733 microprobe at the Microprobe Laboratory at the University of Dalhousie.

Accelerating voltage:	15 kV
Probe Current :	5-10 nA
Beam :	defocussed 10 μ beam
Analyzing Crystal :	LIF: Cr, Mn, Fe, Ni, Mg, Cu, Zn, Co, Cd
	TAP: Na, Al, Si, P, F
	PET: K, Ca, Ti, V, S
Counting times:	30 seconds at peak position
	30 seconds at both background
Number of analysis points :	2-4 points per sample
Analytical standards:	Cd: Cd-metal
	Cu: chalcopyrite
	Cr: chrome-diopside
	chromite
	Co: cobaltite
	P : fluorapatite
	Si: jadeite
	Al: jadeite
	Na: jadeite
	Ca: kaersutite
	Mg: kaersutite
	Ti: kaersutite
	Fe: magnetite
	sphalerite
	Mn: MnO_2
	Ni: Ni-metal
	K : sanidine
	Zn: sphalerite
	willemite
	S : sphalerite
	V : V-metal

Table 5-3: Wavelength - dispersive analyses of rubies from various localities

OXIDE	1	2	3	4	5	6	7	8
Al_2O_3*	99.288	98.653	98.963	98.976	97.149	99.117	99.124	99.343
SiO_2	0.019	0.019	0.000	0.095	0.117	0.087	0.066	0.090
MgO	0.032	0.006	0.006	0.025	0.076	0.000	0.022	0.025
Na_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TiO2	0.019	0.019	0.010	0.019	0.038	0.035	0.023	0.036
V_2O_5	0.000	0.033	0.000	0.082	0.070	0.082	0.116	0.107
Cr_2O_3	0.274	0.385	0.252	0.624	1.407	0.564	0.482	0.203
MnO	0.006	0.000	0.000	0.069	0.069	0.039	0.053	0.055
FeO	0.357	0.848	0.760	0.043	0.987	0.044	0.048	0.055
CoO	0.000	0.028	0.000	0.017	0.042	0.017	0.028	0.042
NiO	0.005	0.011	0.011	0.050	0.044	0.016	0.038	0.044
TOTAL	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

* Difference from 100% assumed to be Al_2O_3

1. Thailand; GIA - 12427B; 0.54ct
2. Phillipsburg, Montana, USA; GIA - 15723; 0.50ct
3. East Africa; GIA - 2637; 0.31ct
4. Burma; GIA - 12401B, 0.25ct
5. Sri Lanka; GIA - 6992; 0.18ct
6. Afghanistan; GIA - 12993; 0.64
7. Burma; GIA - 11649; 0.35ct
8. Sri Lanka; GIA - 11432; 1.20ct

Table 5-4: Error calculations (99% confidence level) based on the counting statistics for the trace elements analysed in ruby samples.

RACE ELEMENTS	WEIGHT % ERROR (+/-)
Ti	0.024
Fe	0.039
V	0.063
Co	0.018
Cr	0.026
Mn	0.084
Si	0.032
Ni	0.051
Mg	0.042

Table 5-5: The weight percentage of the trace elements of rubies in this study compared to those avalilable in the GemIdent data base.

OXIDES	This study MIN - MAX	GemIdent data base MIN - MAX
SiO_2	0.000 - 0.117	0.000 - 0.542
MgO	0.000 - 0.076	0.000 - 0.200
TiO_2	0.010 - 0.038	0.000 - 0.100
V_2O_5	0.000 - 0.107	0.000 - 0.058
Cr_2O_3	0.203 - 1.407	0.000 - 1.810
MnO	0.000 - 0.069	0.000 - 0.000
FeO	0.044 - 0.987	0.000 - 0.200
CoO	0.000 - 0.042	0.000 - 0.000
NiO	0.005 - 0.044	0.000 - 0.000

Table 5-6: Microprobe analysis of an andalusite (Al_2SiO_5) from an unknown locality (GIA 16561, 0.22ct)

OXIDE	1
SiO_2	36.83
TiO_2	0.04
Al_2O_3	61.84
Cr_2O_3	0.01
FeO	0.33
MnO	0.01
MgO	0.05
CaO	0.01
Na_2O	0.01
K_2O	0.01
P_2O_5	0.02
TOTAL	99.16

Table 5-7: Microprobe analysis of a chrome-rich diopside ($CaMgSi_2O_6$) from U.S.S.R. (GIA 1943, 1.35 ct.)

OXIDE	1
SiO_2	54.37
TiO_2	0.05
Al_2O_3	0.21
Cr_2O_3	0.54
FeO	1.18
V_2O_5	0.04
MnO	0.06
MgO	18.04
CaO	25.20
Na_2O	0.42
K_2O	0.00
TOTAL	100.11

Table 5-8: Microprobe analyses of chrysoberyl ($BeAl_2O_4$).

OXIDE	1	2
SiO_2	0.06	0.06
TiO_2	0.04	0.03
Al_2O_3	80.18	79.80
V_2O_3	0.04	0.00
Cr_2O_3	0.08	0.03
FeO	0.04	0.32
MnO	0.01	0.01
MgO	0.09	0.07
CaO	0.00	0.00
NaO	0.00	0.01
BeO*	19.46	19.67
TOTAL	100.00	100.00

* Differene from 100% assumed to be BeO

1. Burma, GIA 3916, 0.08ct

2. Ratnapura, Sri Lanka, GIA 16137, 2.47ct

Table 5-9: Microprobe analysis of cordierite ($Mg_2Al_4Si_5O_{18}$) from Brazil (GIA 16559, 0.70ct)

OXIDE	1
SiO_2	48.83
TiO_2	0.00
Al_2O_3	32.74
FeO	3.36
MnO	0.09
MgO	11.58
CaO	0.02
Na_2O	0.21
K_2O	0.01
H_2O*	3.16
TOTAL	100.00

* Difference from 100% assumed to be H_2O

Table 5-10: Microprobe analyses of danburite ($CaB_2(SiO_4)_2$) and sinhalite ($MgAlBO_4$).

OXIDE	1	2
SiO_2	48.91	0.07
Al_2O_3	0.08	39.95
FeO	0.04	1.74
MgO	0.00	30.78
CaO	23.12	0.01
B_2O_3*	27.85	27.45
TOTAL	100.00	100.00

* Difference from 100% assumed to be B_2O_3

1. Danburite, Locality unknown, GIA - 3197 1.54ct

2. Sinhalite, Sri Lanka, GIA - 681, 4.93ct

Table 5-11: Microprobe analyses of grossular garnets ($Ca_3Al_2(SiO_4)_3$).

OXIDE	1	2	3
SiO_2	39.40	40.08	39.64
TiO_2	0.53	0.42	0.41
Al_2O_3	21.60	21.61	21.72
Cr_2O_3	0.01	0.01	0.00
FeO	1.03	0.54	1.55
MnO	0.39	0.34	0.37
MgO	0.47	0.38	0.32
CaO	36.89	36.52	36.59
TOTAL	100.32	99.90	100.60

1. Brazil, GIA - 4380a, rough piece

2. Brazil, GIA - 4380b, rough piece

3. Brazil, GIA - 4350c, rough piece

Table 5-12: Microprobe analyses of two rough fragments of kunzite ($LiAlSi_2O_6$) from Afghanistan.

OXIDE	1	2
SiO_2	65.03	65.38
Al_2O_3	27.53	27.68
FeO	0.00	0.00
MnO	0.03	0.00
MgO	0.00	0.09
CaO	0.00	0.01
Na_2O	0.10	0.00
K_2O	0.11	0.14
Li_2O*	7.91	6.68
TOTAL	100.00	100.00

* Difference from 100% assumed to be Li_2O

Table 5-13: Microprobe analyses of prehnite ($Ca_2Al_2Si_3O_{10}(OH)_2$)from an unknown locality (GIA 7092, 2.66 ct).

OXIDE	1
SiO_2	42.38
TiO_2	0.00
Al_2O_3	23.49
FeO	0.26
MnO	0.01
MgO	0.01
CaO	27.48
Na_2O	0.08
K_2O	0.01
P_2O_5	0.06
H_2O*	6.22
TOTAL	100.00

* Difference from 100% assumed to be H_2O

Table 5-14: Microprobe analyses of sphalerite (Zn,Fe)S.

Elements	1	2
Zn	65.57	66.06
Fe	0.65	0.13
S	32.47	33.65
Cu	0.03	0.05
Mn	0.02	0.01
Cd	0.48	0.27
Co	0.02	0.02
TOTAL	99.24	100.19

1. Japan, GIA 844, 0.70ct

2. Spain, GIA 2038, 6.85ct

Table 5-15: Microprobe analyses of tanzanite and zoisite ($Ca_2Al_3(SiO_4)_3(OH)$).

OXIDE	1	2	3
SiO_2	39.62	39.77	39.55
TiO_2	0.04	0.04	0.05
Al_2O_3	33.15	33.61	33.19
Cr_2O_3	0.05	0.03	0.03
FeO	0.01	0.00	0.00
MnO	0.02	0.00	0.01
MgO	0.23	0.07	0.05
CaO	25.15	25.07	24.93
Na_2O	0.05	0.01	0.01
K_2O	0.02	0.00	0.00
H_2O*	1.66	2.00	2.18
TOTAL	100.00	100.00	100.00

* Difference from 100% assumed to be H_2O

1. Tanzanite, Locality unknown, GIA - 3812, 1.41ct

2. Tanzanite, East Africa, GIA - 2446, 0.85ct

3. Zoisite, East Africa, GIA - 2415, 0.72ct

Table 5-16: Microprobe analysis of willemite (Zn_2SiO_4) from Franklin, New Jersey, U.S.A. (GIA 3617, 0.31 ct)

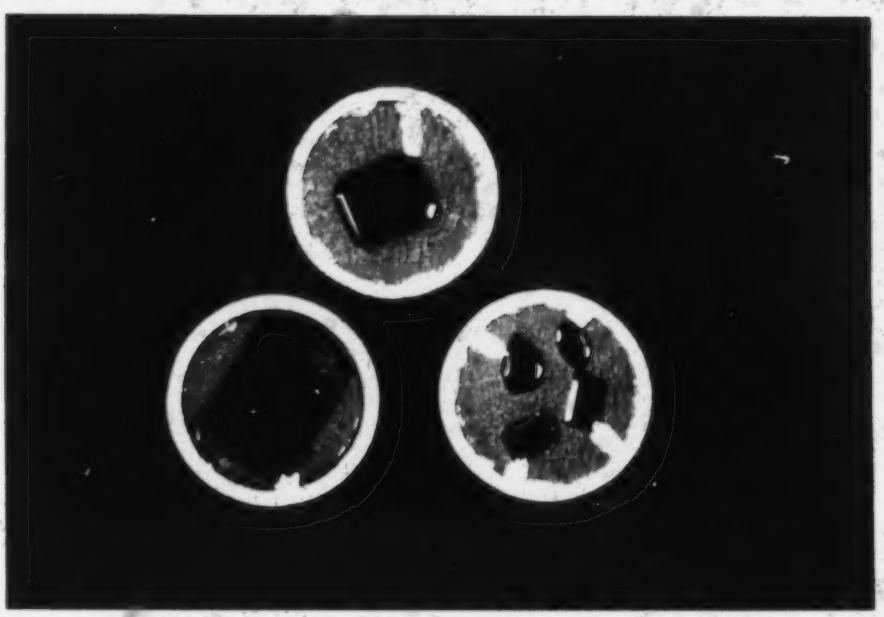
OXIDE	1
SiO_2	28.64
Al_2O_3	0.00
Cr_2O_3	0.00
FeO	0.10
MnO	7.61
MgO	0.19
ZnO	63.20
Cuo	0.00
TOTAL	99.74

Table 5-17: GemIdent procedures and results based on microprobe data of danburite.

```
UNKNOWN
W Si=MAJOR
W Ca=MAJOR
W B =MAJOR
SAVE
MATCH
Scanning within GEMS  division.
425 minerals examined,  0 ignored, 420 not matched and
    5 matched.

TABULATE NAME TM W SiO2 W CaO W B2O3
```

Name	TM	SiO2	CaO	B2O3
DANBURITE	100.0	27.829	23.599	26.358
DATOLITE	100.0	37.172	35.252	20.978
HOWLITE	100.0	15.155	28.355	44.97
LIDDICOATITE	99.8	37.533	2.27	10.535
UVITE	100.0	35.827	3.767	10.805



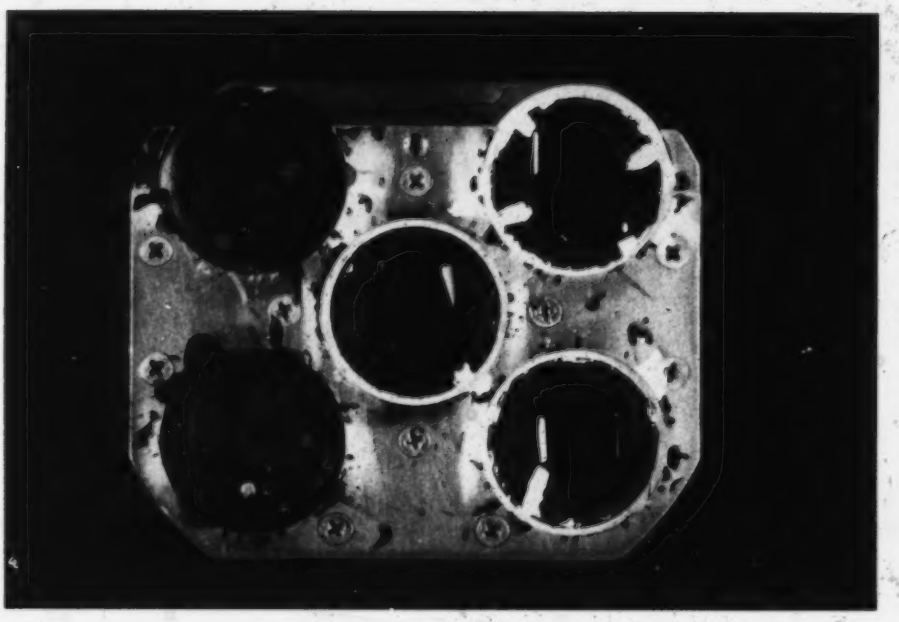


Plate 5-1: Photographs of faceted gems mounted in apiezon putty.

CHAPTER 6:

CONCLUDING REMARKS

The GemIdent data base improves the accessibility of data in the literature, and provides an effective link among people who generate, interpret, apply, and publish data, and the primary literature. The literature of the past decade has witnessed a thrust in the physical, optical, and chemical documentation of gems, and gemmology has become a more quantitative science. This has largely been a result of the advent of gem-quality synthetics, and the many nondestructive analytical techniques which are being applied in order to distinguish between natural and synthetic gems. The rapid advances in commercial synthetic production have resulted in continual variation and improvement of gem-quality synthetics, which in turn have contributed to the difficulty of distinguishing between naturals and synthetics. More important however, has been the need to compare the data collected from synthetics to well documented ranges of properties for their natural counter parts. GemIdent partially fulfils this role, as it represents the first literature compilation of selected gem data for over 280 naturally occurring gem minerals. The properties included are compositional, optical and physical in nature.

The application of the electron microprobe as a nondestructive technique for compositional characterisation of gems has been demonstrated, although its full potential has not yet been realised. Microprobe analyses of gem-quality minerals have been compiled for the GemIdent data base. In addition, a number of wavelength dispersive analyses for a wide variety of gems has been contributed in this study. Standard gemmological properties such as refractive indices, density, fluorescence, absorption spectra etc., have also been included in the data base. Furthermore, provisions have been made for the recording of inclusions, occurrence and locality, as well as collection number and details of the cut.

Data bases in general, must be complete and up to date, correct, versatile, and "user friendly". In GemIdent it has been necessary to supplement the gemmological literature with data from the mineralogical literature, in order to complete the data base. As more data on gem-quality material become available, the data can be replaced. Given the exponential growth of gem data, the data base can become out dated very rapidly if continued efforts are not made to stay abreast of published and unpublished data. Another important aspect of any data base is the accuracy of the data contained in it. This is critical in GemIdent, since successful retrievals and identifications depend on this criterion. It is inevitable that GemIdent will contain some

errors and special attention has been devoted to this aspect of the data base. The software checks for consistency of some parameters has minimised errors. Versatility and "user friendliness" of the GemIdent software are also important, where the aim has been for the program to diagnose problems with user inputs and respond with helpful messages. The "user friendliness" of the GemIdent program can be improved by implementation of selection menus, rather than its present command driven status. The online help facility has been designed for easy access to necessary procedures.

The unique aspects of the GemIdent data base are the structure of the data base, the capabilities of the software in terms of selection, integration, and comparison of gem data, and the assignment of matching indices in identification procedures. It allows for rapid and efficient access to a large number of parameters which can be viewed in SAMPLE, GENERAL, or COMPILED DATA DISPLAYS. Being the first undertaking of its kind, the choice of parameters has been based largely on their potential as a determinative property, the universality of the property being measured or described, and the availability of data. Since no previously designated and widely accepted standard exists for the recording of data pertaining to some of the chosen parameters, it has been essential to implement syntax and semantics which were not only acceptable scientifically, but which would also lend themselves to computerisation.

It is hoped that the conventions adopted in this data base will be accepted and used by the gemmological community.

The selection, integration, and comparison of gem data, as well as identification of gems, involve a combination of the MATCH, IDENTIFY, TABULATE, and DISPLAY commands. The fundamental difference between MATCH and IDENTIFY, is that MATCH searches for gem minerals which exactly match the UNKNOWN DATA, while IDENTIFY does not reject any gem mineral but selects the most likely matches. In both cases matching indices are calculated and presented in terms of a TOTAL MATCHING (TM) INDEX. The TM index is a reflection of the closeness of the match, and degree of mismatch as well as the importance of the parameter that did not match. The two approaches for searching the data base may be combined, where the MATCH procedure is used for a preliminary reduction in the number of possibilities and the IDENTIFY procedure, for selection of the 20 most likely candidates with the highest TM values.

The retrieval and comparison of gem data is facilitated by the MATCH, TABULATE, and DISPLAY commands. Retrievals can be based on the name, SAMPLE/GENERAL RECORD NUMBERS, as well as gemmological properties. Interpretation and comparison of gem data is facilitated by the TABULATE command which permits the listing of physical, optical, and chemical parameters, side by side. The classification scheme

implemented for the GemIdent data base, permits examination of ranges of various properties within a division. In addition, the SUBSET facility can be used for restricting the data base to chemically similar gem minerals or any other related group of gems.

Computer processing of data cannot replace scientific interpretation of results, it simply permits rapid and efficient access to relevant data. Artificial intelligence techniques may be able to change data handling by computers into a more intelligent role, capable of analysis and interpretation. Future developments of the GemIdent data base depend largely on its success as a gemmological data base. There are many avenues for further developments, especially with respect to linking with other specialised data bases which may be developed, and applications in computer aided teaching.

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APPENDIX I: GemIdent User Manual

This is an appendix in which GemIdent commands, variables and parameters have been summarised. It is intended to provide the necessary information for users of GemIdent. The data base management side of the program contains facilities to modify the data base through additions, deletions, and editing capabilities. This aspect of the program will not be used by most users of GemIdent, and therefore has been omitted from this manual. The online HELP facility contains the contents of this manual, and it may be accessed at any time. A list of terms that may be explained in this way may be obtained by typing LIST.

Any statement that can be recognized by GemIdent is considered a command. Thus there are commands which set the values of parameters, and there are commands which implement certain procedures. For each of the parameters, variables and commands, a combination of the following items has been used for their description:

form:	the syntax used by the program. The minimum abbreviation is in uppper case.
context:	the relation of the parameter, variable, or command to the types of data (e.g. sample, mineral etc.,) or parameters.
definition:	a short definition of the parameter, variable or command.
usage:	the combination of the syntax and semantics that may be used GemIdent.
{} (braces):	enclose terms that should be replaced appropriately.
()(parentheses):	enclose optional material.
units:	the units of the parameter.
default:	the value assumed by the program unless specified otherwise.
example:	examples demonstrating the item.
note:	additional comments.

The structure of the data base, types of data, special facilities, and applications of GemIdent were discussed in chapters 2 and 3. All symbols and terms that command GemIdent to perform certain actions are shown in alphabetical order in this manual.

symbol

Form: #
Def: This symbol prefixes GemIdent commands. It is needed in REQUEST mode in order to inform GemIdent that input is not a response to a request, but a command to be executed. After the command is executed the request is made again.
Context: GemIdent command issuable anytime.
Usage: #(GemIdent command) input is a command, not a value
Example:

```
N(alpha)""? 1.504          incorrect value
                           entered
N(beta)""? #n(alpha)=1.405 correction made
N(beta)""? 1.435           next value entered
N(gamma)""?                next request
```

Note: This symbol is redundant when REQUEST=OFF, since all inputs are assumed to be commands.

$ Command

Form: $
Def: Symbol used to prefix DOS commands issued from within GemIdent.
Context: GemIdent command issuable anytime.
Usage: $(DOS command) The dollar sign symbol prefixes DOS commands
Note: This command may not work if there is not enough memory available.
Example:

```
$type $p.min     display contents of file
                 "$p.min"
$command         enter MS-DOS command
                 processor; type EXIT to
                 return
$dir             list the user's files
```

* Command

Form: *
Def: The asterisk symbol prefixes comments that are intended to be ignored. This is useful as a "print" statement in a batch file.
Context: GemIdent command issuable anytime.
Usage: *(comment)
Example:

```
*This will be ignored.|*So will this
*This is also ignored|but this is not
```

- Symbol

Form: -
Def: The dash symbol informs GemIdent that the next line entered is part of the previous line. This may be needed where long lines are entered (such as for remarks), otherwise some systems will truncate them.
Context: GemIdent command issuable anytime.
Usage: {start of a command}-
{middle of a command}-
{end of a command}
Example: remarks=This gem is usually cut with the-
table nearly perpendicular to the c-axis, -
thus producing the deepest colour.
Note: a dash should not be used as a hyphen to split up a word at the end of a line because the dash is replaced by a space.

: Symbol

Form: :
Def: The colon symbol invokes the system editor.
Context: GemIdent command issuable anytime.
Usage: : edits the current request
{parameter}=: edits the parameter's contents

@ Symbol

Form: @
Def: The at symbol appends the input line to the existing content.
Context: GemIdent command issuable anytime.
Usage: @{line} appends line to requested parameter's value
Used when REQUEST=on
{parameter}=@{line} appends line to parameter's value.
Used when REQUEST=off
Example: If REMARKS contain "Gem has good cleavage.", then entry of either:
1) remarks=@It is also brittle.
2) Remarks"Gem has good cleavage."@It is also brittle.
causes it to contain:
"Gem has good cleavage. It is also brittle".
Note: A space is inserted between the default and appended value.

a parameter

Form:	A	
Def:	Unit cell edge dimension.	
Context:	General, sample and unknown data; tabulate parameter	
Usage:	A	displays value
	A=(range)	assigns value
	tab A	tabulates value
	tab EDG	tabulates A, B and C unit cell edges
	tab DIM	tabulates ALPHA, BETA, GAMMA, A, B and C cell dimensions
Units:	0.0 - 150.0 angstrom units	

absorption-spectra parameter

Forms:	ABSorption-spectra, SPEctra	
Def:	The continuous spectra of all the wavelengths. In gemology, it is commonly restricted to the visible part of the electromagnetic spectrum. This property can be obtained with hand held spectroscopes or elaborate spectrophotometer.	
Context:	General, sample and unknown data; tabulate parameter	
Usage:	ABS	displays values
	ABS=(spectra),..up to 20 times	assigns values
	tabulate (LENgth (length)) ABS	tabulates values
(spectra):	x a single (narrow, normal, strong or weak) line	
	x-y a single (broad) band	
(length):	minimum=15, default=48, maximum=300	
Units:	380nm - 700nm	
Example:	spe=450,475,525-575,690	

all parameter

Context:	tabulate parameter.	
Usage:	tab (pars)... ALL (pars)...	tabulates the parameters for all gems in the data base.
Example:	tabulate all name formula	
Note:	Tabulation is alphabetical.	

alpha parameter

Form:	ALPha

Def:	Unit cell angle.	
Context:	General, sample and unknown data; tabulate parameter.	
Usage:	ALPha	displays value
	ALPha=(range)	assigns value.
	tabulate ALP	tabulates value
	tabulate ANG	tabulates ALPHA, BETA and GAMMA unit cell angles
	tabulate DIM	tabulates ALPHA, BETA, GAMMA, A, B and C dimensions
Units:	0.0 - 180.0 degrees	
Note:	See ANGLE-ENTRY for assigning values to cell angles.	

angle-entry

UNITS: 0.0 - 180.0 degrees
Angles may be entered in any of the following ways:

Entry	Decimal	Meaning
12	12.0	12 degrees
12.5	12.5	12 degrees, 30 minutes,
12:30	12.5	12 degrees, 30 minutes,
12:34.5	12.575	12 degrees, 34 minutes, 30 seconds
12:34:30	12.575	12 degrees, 34 minutes, 30 seconds
12:34:56.7	12.58242	12 degrees, 34 minutes, 56.7 seconds

Note: All angle entries are converted to decimal form. The above applies to ALPHA, BETA and GAMMA entries.

angles parameter

Form:	ANGles	
Def:	The alpha, beta & gamma unit cell angles.	
Context:	Tabulate parameter	
Usage:	tabulate ANGles	tabulates the unit cell angles.

attention key

Forms:	ATTENtion, BREAK, ^C, CONTROL-C, CONTROL-BREAK (CONTROL-SCROLL LOCK) keys.
Def:	Hitting this key will abort the last command, i.e., it will stop listings in progress,

suspend batch processing (equivalent to the BATCH PAUSE command), exit request loops, etc.

Context: GemIdent command issuable anytime.
Usage: ATTEN equivalent to hitting the CONTROL-C
Note: Unlike the SAVE command, an attention will exit the add or edit request loop for general, sample, mineral or synonym data WITHOUT saving the data.

average parameter

Forms: AVErage
Context: tabulate parameter
Def: Compiled data consist of minimum, average and maximum values.
Usage: tab (pars)... AVE (pars)..tabulates average parameter values
Default: The average parameter values are tabulated by default.
Example: tabulate name average density

b parameter

Form: B
Def: Unit cell edge dimension.
Context: General, sample and unknown data; tabulate parameter

Usage:

B	displays value
B=(range)	assigns value
tabulate B	tabulates value
tabulate EDG	tabulates the A, B and C unit cell edges.
tabulate DIM	tabulates the ALP, BET, GAM, A, B and C dimensions.

Units: 0.0 - 150.0 angstrom units

beta parameter

Form: BETa
Def: Unit cell angle dimension
Context: General, sample and unknown data; tabulate parameter.
Usage:

BET	displays value
BET=(range)	assigns value
tabulate BET	tabulates value
tabulate ANG	tabulates the ALPHA, BETA and GAMMA unit cell angles
tabulate DIM	tabulates the ALP, BET, GAM, A, B and C dimensions

Units: 0.0 - 180.0 degrees

birefringence parameter

Form: BIRefringence
Def: maximum difference between the refractive indices.
Context: General, sample and unknown data; tabulate parameter
Usage:

BIR	displays value
BIR=(range)	assigns value
tabulate BIR	tabulates value

Rules:
1) If OPC=isotropic then BIR=0.0
2) 0.0 <= BIR <= (NOM-NEP) <= 10.0 (OPC=uniaxial)
3) 0.0 <= BIR <= (NGA-NAL) <= 10.0 (OPC=biaxial)

blank parameter

Form: BLAnk
Context: tabulate parameter
Usage: tab (LEN (len)) BLA tabulates an empty column of specified length.
(len): minimum=1, default=7, maximum=130

c parameter

Form: C
Def: A unit cell edge dimension.
Context: General, sample and unknown data; tabulate parameter.
Usage:

C	displays value
C=(range)	assigns value
tabulate C	tabulates value
tabulate EDG	tabulates A, B and C unit cell edges
tabulate DIM	tabulates ALP, BET, GAM, A, B and C cell dimensions

Units: 0.0 - 150.0 angstrom units

case variable

Form: CASE
Context: GemIdent variable settable anytime.
Usage:

CASE	Displays case in which formulae may be entered.
CASE Single	Formulae will be interpreted as being in one case. Thus elements in the formula must be separated

by subscripts to prevent ambiguities, i.e. "silo2" or "SI1O2" may be entered but not "SIO2" which could be interpreted as either S-I-O2 or SiO2.

CASE Mixed Formulae will be interpreted in mixed case. Thus either "SiO2" or "Si1O2" can be entered.

Default: case=mixed

Note: This variable affects only the processing of the formulae that are entered for the FORMULA parameter of mineral data, the WEIGHT parameters for sample & unknown data and the WEIGHT parameters of the tabulate command.

characters-per-line parameter

Forms: CHAracters-per-line, CPL

Usage: tabulate CPL {cpl}

{cpl}: the maximum number of characters to tabulate in a line.

classify parameter

Form: CLAssify

Def: The classification of a gem division within a mineralogical hierarchy.

Context: Mineral and unknown data; tabulate parameter

Usage:

CLA	shows classification
CLA (AS) {level} (OF) {division} ({division})	classifies gemstone
tabulate LEVel	tabulates level
tabulate DIVision	tabulates divisions

{level}: TOp, Mineral, TYpe, Class, Family, SUPer-group, Group, SUB-Group, SEries, End-member, SPecies, SUB-Species, Polytypes, Variety.

Note: The TREE command displays the classification hierarchy for gem minerals. The level and second division for an unknown are ignored, however, the first division will restrict MATCHing and IDENTification to gems classified within that division, i.e., an unknown classified under feldspars would restrict scanning to feldspars, plagioclase and alkali-feldspars.

Example: The following is part of the classification scheme which includes feldspars.

----------DIVISIONS----------	LEVEL
MINERALS	top
OXIDES Silicates Carbonates	type
TECTOSILICATES Phyllosilicates	class
ZEOLITES Feldspars Feldspathoids	family
PLAGIOCLASE Alkali-feldspars	group
Anorthite ALBITE Microcline	species
Cleavelandite PERISTERITE	variety

Thus:

Division	Classified as
Cleavelandite	variety of albite
albite	species of plagioclase-group and alkali-feldspars

CM parameter

Form: CM
Context: tabulate parameter
Def: The compositional matching (CM) index indicates how well an unknown matches a mineral on the basis of the concentrations of elements present. This is the most important index for GemIdent.
Usage: tabulate CM tabulates the index

cnrecords command

Form: CNRECords
Context: GemIdent command available anytime.
Usage: CNREC=(cn) lists all the sample records with collection-numbers beginning with (cn).
Note: Collection numbers are entered via the CN command.

collection-number parameter

Forms: COLLection-number, CN
Def: The abbreviation for the location and number of a gem sample.

Context: Sample data, tabulate parameter.
Usage: CN displays
CN=(number) assigns
tabulate CN tabulates
Example: CN=NMNH 463
Units: 0 - 20 characters
Note: The CNRECords command may be used to locate gem samples from particular collections.

ColorMaster-cause parameter

Forms: COLORMASTER-Cause CMCause
Context: tabulate parameter; sample ColorMaster-colour data
(cause): Dominant|Change|Pleochroism|
Shift|Windowing|Zoning

Dominant is the default cause.
The dominant or key colour of a gem is always graded with the GIA's Colored Stone Grading System. Where additional colours are present and are moderate to strong, caused by colour change, pleochroism, shift, windowing or zoning, they must also be graded. These additional colours are defined as:

A) Colour change is a visible difference in the colour of a gem under daylight equivalent and incandescent light source of the ColorMaster.
B) Pleochroism is the phenomenon that results from double refraction and tends to concentrate at the ends or tips on a faceted gem, when viewed under the daylight equivalent light source.
C) Colour shift is an additional colour, often higher in saturation than the dominant colour, seen in singly refractive stones under the daylight equivalent light source.
D) Windowing is present often in the center of poorly cut stones, and while it usually has the same hue and tone as the dominant colour, it is less saturated.
E) Colour zoning is only graded when the stone has been purposely cut in order to juxtapose areas of different colour. Only intended colour zoning is graded with the ColorMaster.

Usage: tabulate CMC tabulates value

ColorMaster-colour parameter

Forms: COLORMASTER-COlour CMCOlour CMCOlor
Def: The GIA's Colored Stone Grading System is used to describe the colour of transparent coloured gems that are routinely seen in the marketplace.
Context: Sample data; tabulate parameter.
Usage:

CMCOlour		displays	value
CMCOlour=(colour)(,(colour))(,(colour))		assigns	value
tab COLORMASTER-COlour	CMCOlour	tabulates	all values
tab COLORMASTER-Cause	CMCause	tabulates	sub-value
tab COLORMASTER-STrength	CMSTrength	tabulates	sub-value
tab COLORMASTER-Notation	CMNotation	tabulates	sub-value
tab COLORMASTER-Hue	CMHue	tabulates	sub-value
tab COLORMASTER-Tone	CMTone	tabulates	sub-value
tab COLORMASTER-Saturation	CMSaturation	tabulates	sub-value

(colour): (CMCause) (CMSTrength) ((HTS)|(CMNotation))
(HTS): (CMHue) (CMTone)/(CMSaturation)
Examples: colour=dominant C 34 58 22, change weak G 14 48 12
colour=dominant OR 3/4
Note: GemIdent converts between the HTS and CMN notations. When a stone has no additional colours, it is not necessary to specify the strength. If a stone has an additional colour, it is separated from the dominant colour with a comma, as shown in first example. The sample ColorMaster-hues are compiled and matched/identified with the unknown ColorMaster-hues.

ColorMaster-hues parameter

Forms: COLORMASTER-Hues CMHues
Context: unknown data; sample ColorMaster-colour data; tabulate parameter
(hue):

#	ColorMaster Hue Terms	Abbr.
01	Purple	P
02	reddish Purple	r P
03	Red-Purple/Purple-Red	RP/PR
04	strongly purplish Red	st p R

05	slightly purplish Red	sl p R
06	Red	R
07	orangy Red	o R
08	Red-Orange/Orange-Red	RO/OR
09	reddish Orange	r O
10	Orange	O
11	yellowish Orange	y O
12	orangy Yellow	o Y
13	Yellow	Y
14	greenish Yellow	g Y
15	Yellow-Green/Green-Yellow	YG/GY
16	strongly yellowish Green	st y G
17	yellowish Green	y G
18	slightly yellowish Green	sl y G
19	Green	G
20	very slightly bluish Green	v sl b G
21	slightly bluish Green	sl b G
22	strongly bluish Green	st b G
23	Green-Blue/Blue Green	GB/BG
24	very strongly greenish Blue	v st g B
25	greenish Blue	g B
26	very slightly greenish Blue	v sl g B
27	Blue	B
28	violetish Blue	v B
29	bluish Violet	b V
30	Violet	V
31	bluish Purple	b P
32	Orange-Brown	OBrn
33	Yellow-Brown	YBrn
34	orangy Brown	o Brn
35	yellowish Brown	y Brn

Note: spaces must appear between abbreviations, i.e., GemIdent cannot distinguish between "oR" and "OR". Enter "o R" or "OR".

Usage:		
CMH	displays	value
CMH=(hue)...	assigns	value
tabulate CMH	tabulates	value

ColorMaster-notation parameter

Forms: COLORMASTER-Notation CMNotation

Context: sample ColorMaster-colour data; tabulate parameter.

{CMN}: {filter} {red} {green} {blue}

{filter}: A-G. One of these colour filters must be selected before dialing the appropriate amounts of red, green and blue lights.

{red}: 0-100. Any hue can be produced by the appropriate amount of red, green and blue light. In the ColorMaster, the amount of red light is controlled by the red knob and the numerical value is taken from the digital readout.

{green}: 0-100. The amount of green light is controlled by the green knob on the ColorMaster and the numerical value is taken from the digital readout.

{blue}: 0-100. The amount of blue light is controlled by the blue knob on the ColorMaster and the numerical value is taken from the digital readout.

Usage: tabulate CMN tabulates value

Example: C 16 13 49

ColorMaster-saturation parameter

Forms: COLORMASTER-Saturation CMSaturation

Context: sample COlorMaster-colour data; tabulate parameter

Definition: The dimension of colour that relates to the "strength" or "intensity" of the colour sensation. Warm colours (red, orange, yellow, brown) tend to be brownish when desaturated, while cold colours (blue, green, violet) tend to be grayish when desaturated, thus two separate saturation word scales exist.

{saturation}:

#	ColorMaster Saturation Terms	Abbr.
1	grayish/brownish	gr/br
2	slightly grayish/ slightly brownish	sl gr/ sl br
3	very slightly grayish/ very slightly brownish	v sl gr/ v sl br
4	moderately strong	m st
5	strong	st
6	vivid	v

Usage: tabulate CMS tabulates value

ColorMaster-strength parameter

Forms: COLORMASTER-STrength CMSTrength CMR

Context: sample ColorMaster-colour data; tabulate parameter

{strength}: Weak|Moderate|Strong|Vague|Distinct|SHarp|(none)

(none) valid only for non-dominant caused colours. The strength of the additional colours caused by colour change, pleochroism, colour shift and windowing is described as being weak, moderate or strong. The demarcation between the two colours present (it is arbitrary which colour is entered as

dominant or additional) is described by the terms vague, distinct or sharp.

Usage: tabulate CMST tabulates value

ColorMaster-tone parameter

Forms: COLORMASTER-Tone CMTone

Context: sample ColorMaster-colour data; tabulate parameter

Def: the dimension of colour that relates to the lightness or darkness of a colour sensation. There are 11 tones but only 7 (tone 2 through 8) are used in grading the transparent coloured gems.

{tone}:

#	ColorMaster Tone Terms	Abbr
00	colorless/white	c/w
01	extremely light	ex l
02	very light	v l
03	light	l
04	medium light	m l
05	medium	m
06	medium dark	m dk
07	dark	dk
08	very dark	v dk
09	extremely dark	ex dk
10	black	bl

Usage: tabulate CMT tabulates value

colour-entry

Context: format of colour entry for DC, DCR, DCOmega, DCEpsilon, PLC, PCAlpha, PCBeta, PCGamma, FLR, FLWuv, FSWuv, FXRay general, sample and unknown data.

{colour}: ({tone}) ({hue}) {hue}

{tone}:

Dark, Deep,	D
PALe, Light,	L

{hue}:

BLAck,	BK
BLUe, BLUish,	BU
BRownish,	BR
Colourless,	CL
GREEnish,	GN
GREYish,	GY
LILacish,	LL
Orange,	OR
PInkish,	PK
PUrple, Purplish,	PP
Reddish,	RD
Violet,	VT

	White,	WT
	Yellowish,	YL
	INert	IN (Fluorescences)

Examples: green, pale green, bluish green, light bluish green

Note: Blue green is a different colour than green blue. Also, the use of the "ish" ending has no effect, i.e., green and greenish are equivalent. In DISPLAYs and TABULATions, only the above abbreviations for the tone and hue are given..

colours

GemIdent uses two different colour notations for various parameters:

1) ColorMaster-colour
2) Pleochroic-colours
   - Pleochroic-colour(alpha)
   - Pleochroic-colour(beta)
   - Pleochroic-colour(gamma)
   - Dichroscope-colour
   - Dichroic-colours
   - Dichroic-colours(omega)
   - Dichroic-colours(epsilon)
   - Fluorescences
   - Fluorescence(Long-wave-ultraviolet)
   - Fluorescence(Short-wave-ultraviolet)
   - Fluorescence(X-ray)

cut-depth parameter

Form: CUT-Depth, CTDepth
Def: The depth of a gemstone's cut dimension.
Context: Sample data, tabulate parameter.
Usage:

CTD	displays value
CTD=(range)	assigns value
tabulate CTD	tabulates value
tabulate CUT	tabulates CTD, CTG, CTL, CTT, CTWE and CTWI

Units: 0.0 - 200.0 mm

cut-length parameter

Forms: CUT-Length, CTLength
Def: The length of a gemstone's cut dimension.

Rectangles:	longest end-to-end size (not diagonal).
Hearts:	distance between point & imaginary line across lobe tops.
Triangles:	perpendicular distance from center of width side to opposite point.

Others: longest dimension.
Context: Sample data, tabulate parameter.
Usage:

CTL	displays value
CTL=(range)	assigns value
tabulate CTL	tabulates value
tabulate CUT	tabulates CTD, CTG, CTL, CTT, CTWE and CTWI

Units: 0.0 - 200.0 mm

cut-type parameter

Forms: CUT-Type, CTType
Def: The shape or cutting style of the gemstone.
Context: Sample data, tabulate parameter.
Usage:

CTT	displays value
CTT=(type)	assigns value
tabulate CTT	tabulates value
tabulate CUT	tabulates CTD, CTG, CTL, CTT, CTWE and CTWI

(type): Rectangular Cushion, Rectangular Antique Cushion, Rectangular Step Cut, Square Cushion, Square Antique Cushion, Square Step Cut, Heart, Pear, Marquise, Oval, Round, Mixed.
Units: 0 - 30 characters.

cut-weight parameter

Forms: CUT-Weight, CTWEight
Def: Gemstones are weighed in metric carats, which must be accurate to half a point (2 decimal points). Diamond weights are rounded up ONLY when within 0.001 carat (i.e., 0.378 carat rounds to 0.37 while 0.379 rounds to 0.38).
Context: Sample data, tabulate parameter.
Usage:

CTW	displays value
CTW=(range)	assigns value
tabulate CTW	tabulates value
tabulate CUT	tabulates CTD, CTG, CTL, CTT, CTWE and CTWI

Units: 0.01 - 100.0 carats.
Note: 1 (metric) carat = 100 points.
1 (metric) carat = 0.200 grams.

cut-width parameter

Forms: CUT-WIdth, CTWIdth
Def: A gemstone's cut dimension.

Rounds: average minimum and maximum girdle diameters.

```
                Squares:     average of the two side-to-side
                             measurements.
                Rectangles:  perpendicular to length.
                Hearts:      widest parts of the lobes.
                Triangles:   shortest corner-to-corner distance.
                Others:      perpendicular to length.
        Context:    Sample data, tabulate parameter.
        Usage:      CTWI            displays  value
                    CTWI=(range)    assigns   value
                    tabulate CTWI   tabulates value
                    tabulate CUT    tabulates CTL, CTWI, CTD,
                                    CTWE, CTT & CTG
        Units:      0.0 - 200.0 mm
```

data parameter

```
        Form:       DATA
        Def:        The tabulate command displays rows which
                    consists of the following types of data:
                    CAVE - average compiled data (tab ave - default)
                    CMAX - maximum compiled data (tab max)
                    CMIN - minimum compiled data (tab min)
                    GMAX - maximum general data  (tab gen)
                    GMIN - minimum general data  (tab gen)
                    SAMP - sample data           (tab sam)
                    SYNO - synonym data          (tab syn)
                    UMAX - maximum unknown data  (tab unk)
                    UMIN - minimum unknown data  (tab unk)
        Context:    tabulate parameter
        Usage:      tabulate DATA       tabulates the type of
                                        data in the row of
                                        tabulation
```

date parameter

```
        Forms:      DATe, TIME
        Def:        Contains the date and time data was last
                    modified.
        Context:    General/mineral/sample/unknown data, tabulate
                    parameter
        Usage:      DATe        displays  value
                    tab DATe tabulates value
```

default parameter

```
        Form:       DEFault
        Context:    Tabulate parameter
        Usage:      tab DEF equivalent to inserting name,
                    unknown, tm, (and any other parameters
                    entered for the unknown) and formula.
```

Example: For example, if a value for density has been entered for the unknown, then tabulate default is equivalent to entering tabulate name unknown tm density formula

Note: If no parameters have been specified, default is assumed. If a blank line (enter key) is entered, GemIdent will assume that the default shown was meant to be entered. See REQUESTs. Defaults inform GemIdent not to change values. For numeric values, empty spaces (before commas) denote defaults. For example, to change the fourth spectrum to 530 and leave the others unchanged, enter: spectra= , , ,530

density parameter

Form: DENsity
Context: General, sample, unknown data, tabulate parameter.
Usage:

DEN	displays	value
DEN=(range)	assigns	value
tabulate DEN	tabulates	value

Units: 0.0 - 25.0 g/cc

dichroic-colour(epsilon) parameter

Forms: DICHROIC-COLOUR(Epsilon), DCEpsilon
Def: Colour corresponding to the extraordinary vibration direction. If the vibration direction is unknown, use the DICHROISM parameter.
Context: General, sample, unknown data, tabulate parameter.
Usage:

DCE	displays	value
DCE=(colour)	assigns	value for sample
DCE=(colour),...6x	assigns	value for general or unknown
tabulate DCE	tabulates	value
tabulate DCR	tabulates	DCR
tabulate DCRS	tabulates	DCE and DCO

(colour): See COLOUR-ENTRY rules.
Rules: Dichroism implies a uniaxial optical-character.
Example: dce=light blue

dichroic-colour(omega) parameter

Forms: DICHROIC-COLOUR(Omega), DCOmega
Def: Colour corresponding to the ordinary vibration direction. If the vibration

direction is unknown, use the DICHROISM parameter.

Context: General, sample, unknown data, tabulate parameter.

Usage:

DCO	displays	value
DCO=((colour))	assigns	value for sample
DCO=((colour)),...6x	assigns	value for general or unknown
tabulate DCO	tabulates	value
tabulate DCR	tabulates	DCR
tabulate DCRS	tabulates	DCEpsilon and DCOmega

{colour}: See COLOUR-ENTRY rules.

Rules: Dichroism implies a uniaxial optical-character.

Example: dco=orange

dichroism parameter

Form: DIChroism, DCR

Def: The phenomenon whereby a mineral shows different colours for light vibrating parallel to the extraordinary and ordinary vibration directions. For specific vibration directions, use the DCE and DCO commands; when the direction is unknown, use the DCR command.

Context: Unknown data; tabulate parameter.

Usage:

DIChroism	displays	value
DIChroism={colour},...6 x	assigns	value
tabulate DIChroism	tabulates	value
tabulate DICHROISMS	tabulates	DCE and DCO

{colour}: See COLOUR-ENTRY rules.

Rules: Dichroism implies optical-character=uniaxial.

dichroisms parameter

Form: DICHROISMS, DCRS

Context: tabulate parameter

Usage: tabulate DCRS tabulate DCO and DCE.
tabulate DCR tabulate DCR.

dichroscope-colour parameter

Forms: DICHROScope-colour, DC

Def: Colour viewed through a dichroscope for isometric minerals.

Context: General, sample and unknown data; tabulate parameter.

Usage:	DC	displays value
	DC=({colour})	assigns value for sample
	DC=({colour}),...6x	assigns value for general or unknown
	tabulate DC	tabulates value
{colour}:	See COLOUR-ENTRY rules.	
Rules:	Dichroscope-colour implies an isometric optical-character.	
Example:	dc=orange	

dimension parameter

Form:	DIMensions
Def:	A, B, C, alpha, beta and gamma unit cell dimensions.
Context:	tabulate parameter
Usage:	tab DIM tabulates a, b, c, ALP, BET and GAM unit cell dimensions.

dispersion parameter

Forms:	DISPersion, DSP	
Def:	The difference between the refractive indices measured using the Fraunhofer B & G lines (6870 & 4308 angstroms respectively).	
Context:	General, Sample and Unknown data; Tabulate parameter	
Usage:	DISP	displays value
	DISP=(range)	assigns value
	tabulate DISP	tabulates value
Units:	0.0 - 0.400	
Example:	disp=0.345	

display command

Form:	Display
Def:	Generates full page data displays.
Context:	GemIdent command request loop.
Usage:	

D All ({type})	displays for all minerals
D General {record}	displays for specified general. See GRECords.
D (MAtched) ({type})	displays for all MATCHed or IDENTified minerals
D (Mineral) ({type}) {mineral}...	displays for specified minerals
D Sample {record}	displays for specified sample. See SRECords.

Usage:	DC	displays value
	DC=({colour})	assigns value for sample
	DC=({colour}),...6x	assigns value for general or unknown
	tabulate DC	tabulates value
{colour}:	See COLOUR-ENTRY rules.	
Rules:	Dichroscope-colour implies an isometric optical-character.	
Example:	dc=orange	

dimension parameter

Form:	DIMensions
Def:	A, B, C, alpha, beta and gamma unit cell dimensions.
Context:	tabulate parameter
Usage:	tab DIM tabulates a, b, c, ALP, BET and GAM unit cell dimensions.

dispersion parameter

Forms:	DISPersion, DSP	
Def:	The difference between the refractive indices measured using the Fraunhofer B & G lines (6870 & 4308 angstroms respectively).	
Context:	General, Sample and Unknown data; Tabulate parameter	
Usage:	DISP	displays value
	DISP={range}	assigns value
	tabulate DISP	tabulates value
Units:	0.0 - 0.400	
Example:	disp=0.345	

display command

Form:	Display
Def:	Generates full page data displays.
Context:	GemIdent command request loop.
Usage:	

D All ({type})	displays for all minerals
D General {record}	displays for specified general. See GRECords.
D (MAtched) ({type})	displays for all MATCHed or IDENTified minerals
D (Mineral) ({type}) {mineral}...	displays for specified minerals
D Sample {record}	displays for specified sample. See SRECords.

D SUbset ((type))	displays for mineral subset
D UNDisplayed ((type))	displays for all minerals modified after last DISPLAY UNDisplayed
D Unknown	displays for unknown

(type):	Compiled	Compiled (min/ave/max) and mineral data are displayed. This is the default type if none specified.
	Generals	General (min/max) and mineral data are displayed.
	Samples	Sample and mineral data are displayed.

Notes:
- The date displayed is the date data was last modified.
- The standard deviations of compositions will be shown only when more than five analyses have been used (compiled data).

divisions parameter

Form:	DIVision
Def:	Gems are classified hierarchically into divisions and LEVELs. For example, cleavelandite belongs to the albite division which belongs to the plagioclase and alkali-feldspars divisions which both belong to the feldspars divisions, which belong to the tectosilicates ...
Context:	tabulate parameter
Usage:	tab (LENgth (len)) DIV tabulates value with specified length
(len):	minimum=8, default=20, maximum=81
Note:	The TREE command will also show divisions of gem minerals. The CLASSIFY command assigns them.

edges parameter

Form:	EDGes
Context:	tabulate parameter
Usage:	tabulate EDGes tabulates the a, b and c unit cell edges

elist parameter

Form:	ELIST
Context:	GemIdent command available anytime

Usage: ELIST lists the elements and their atomic weights. An ATTENTION will stop the listing.

fluorescence parameter

Form: FLUorescence, FLR
Def: The colour of emitted visible light due to excitation by radiation of unknown energy. For specific energies, use the FLWuv, FSWuv and FXRay parameters.
Context: unknown data; tabulate parameter
Usage:

FLUorescence	displays value
FLUorescence=(colour), ...	assigns value
tabulate FLUorescence	tabulates value
tabulate FLUORESCENCES	tabulates Fswuv, FLWuv and FXRay

(colour): See COLOUR-ENTRY

fluorescence(long-wave-ultraviolet) parameter

Form: FLUORESCENCE(Long-wave-ultraviolet), FLWuv
Def: The colour of emitted visible light due to excitation by long-wave ultraviolet radiation. If the radiation is of unknown energy, use the FLUorescence parameter.
Context: Sample, general and unknown data; tabulate parameter.
Usage:

FLW	displays
FLW=(colour)	assigns for samples
FLW=(colour),...up to 6times	assigns for generals & unknowns
tabulate FLW	tabulates
tabulate FLRS	tabulates FLW, FSW & FXR

(colour): See COLOUR-ENTRY rules
Example: flw=green

fluorescence(short-wave-ultraviolet) parameter

Form: FLUORESCENCE(Short-wave-ultraviolet), FSWuv
tabulate CTD tabulates value
tabulate CUT tabulates CTD, CTG, CTL, CTT, CTWE and CTWI
Units: 0.0 - 200.0mm

cut-length parameter

Forms: CUT-Length, CTLength

Def: The length of a gemstone's cut dimension.
Rectangles: longest end-to-end size (not diagonal).
Hearts: distance between point & imaginary line across lobe tops.
Triangles: perpendicular distance from centre of width side to opposite point.
Others: longest dimension.
Context: Sample data, tabulate parameter.
Usage:

CTL	displays value
CTL=(range)	assigns value
tabulate CTL	tabulates value
tabulate CUT	tabulates CTD, CTG, CTL, CTT, CTWE and CTWI

Units: 0.0 - 200.0 mm

cut-type parameter

Forms: CUT-Type, CTType
Def: The shape or cutting style of the gemstone.
Context: Sample data, tabulate parameter.
Usage:

CTT	displays value
CTT=(type)	assigns value
tabulate CTT	tabulates value
tabulate CUT	tabulates CTD, CTG, CTL, CTT, CTWE and CTWI

(type): Rectangular Cushion, Rectangular Antique Cushion, Rectangular Step Cut, Square Cushion, Square Antique Cushion, Square Step Cut, Heart, Pear, Marquise, Oval, Round, Mixed.
Units: 0 - 30 characters.

cut-weight parameter

Forms: CUT-Weight, CTWEight
Def: The colour of emitted visible light due to excitation by short-wave ultraviolet radiation. If the radiation is of unknown energy, use the FLUorescence parameter.
Context: Sample, general and unknown data; tabulate parameter.
Usage:

FSW	displays
FSW=(colour)	assigns for samples
FSW=(colour),...up to 6times	assigns for generals & unknowns
tabulate FSW	tabulates
tabulate FLRS	tabulates FLW, FSW & FXR

(colour): See COLOUR-ENTRY rules
Example: fsw=blue

fluorescence(X-ray) parameter

Form:	FLUORESCENCE(X-ray), FXRay	
Def:	The colour of emitted visible light due to excitation by x-ray radiation. If the radiation is of unknown energy, use the fluorescence parameter.	
Context:	General, sample, tabulate and unknown parameters.	
Usage:	FXR	displays
	FXR=(colour)	assigns for samples
	FXR=(colour),...up to 6x	assigns for generals & unknowns
	tabulate FXR	tabulates
	tabulate FLRS	tabulates FLW, FSW & FXR
(colour):	See COLOUR-ENTRY rules	
Example:	fxr=red	

fluorescences parameter

Form:	FLUORESCENCES, FLRS
Def:	FLW, FSW, FXR
Context:	tabulate parameter
Usage:	tab FLRS tabulates FLW, FSW and FXR
	tab FLR tabulates FLR

formula parameter

Form:	FORmula	
Context:	Mineral data, unknown data, tabulate parameter	
Usage:	FOR	displays value
	FOR=(formula)	assigns value
	tab (LENgth=(len)) FOR	tabulates formula with specified length
(len):	minimum=7, default=33, maximum=100	

gamma parameter

Form:	GAMma		
Def:	Unit cell angle dimension.		
Context:	General, sample or unknown data; tabulate parameter		
Usage:	GAM	displays	value
	GAM=(range)	assigns	value (See ANGLE-ENTRY)

```
                tab GAM_      tabulates value
                tab ANG       tabulates ALPHA, BETA and GAMMA
                              angles
                tab DIM       tabulates ALPHA, BETA, GAMMA,
                              A, B and C dimensions
   Units:       0.0 - 180.0 degrees.
```

generals parameter

```
   Form:        GENerals
   Context:     tabulate parameter
   Usage:       tab (pars)... GEN (pars)... tabulates general
                                            data for the
                                            specified
                                            parameters
   Note:        General data can also be DISPLAYed and SHOWn
```

grecords command

```
   Form:        GRECords
   Context:     GemIdent command available anytime
   Usage:       GREC (mineral) lists the record number and
                sources of all general data for a mineral.
                Useful prior to EDIT GENERAL, DELETE
                GENERAL and DISPLAY GENERAL commands which
                require a general record number.
   Example:     grec kunzite
```

help command

```
   Form:        HELP, EXPlain, ?
   Context:     GemIdent command available anytime
   Usage:       ?          explains the current request
                ? (term)   explains (term)
   Note:        LIST can be used to list all terms that may
                be explained via HELP.
```

identifier parameter

```
   Form:        IDEntifier, NAMe
   Def:         the "name" assigned to an unknown to
                distinguish it from other unknowns.
   Context:     unknown data; tabulate parameter
   Usage:       IDE          displays value
                IDE=(name)   assigns it
                tab IDE      tabulates it in the NAME column of
                             the table
   Units:       0 - 130 characters
   Note:        This is not a MATCHed/IDENTified parameter
```

Example: iden=analyses 123, probably amazonite

identify command

Form: Identify
Context: GemIdent command request loop
Usage: I finds the 20 most likely identities of the unknown by comparing it to all minerals in the data base. However, if a mineral SUBSET is in use, then the unknown will be compared to all minerals in the subset. If the unknown has been CLASSIFied into a division, then only minerals within that division will be compared.

I And finds the 20 most likely identities of the unknown by comparing it to all minerals previously MATCHed or IDENTified. MATCH is normally used first to narrow down the possibilities, then IDENTIFY AND because IDENTIFY is much slower than MATCH.

Note: The TABULATE command can be used to list the identities and show how well they match the unknown. The DISPLAY command can list all information about identified minerals. The difference between MATCH and Identify is that MATCH rejects all minerals that lie outside the range specified for the unknown (e.g., den=3.0-4.0), while IDENTIFY does not reject any, although it assigns lower matching indices for such minerals.

IM parameter

Form: IM
Context: tabulate parameter
Def: The information matching (IM) index reflects the percentage of the properties entered for the unknown that were available in the data base. As the GemIdent data base becomes more complete, the significance of this index will decline.
Usage: tab IM tabulates value

inclusions parameter

Form: INClusions

Context:	General, sample or unknown data; tabulate parameter
Usage:	INC displays value INC=(value) assigns value tab (LEN (len)) INC tabulates value with specified length
(len):	minimum=7, default=33, maximum=130
Units:	0 - 320 characters (for general or sample) 0 - 20 characters (for unknown)
Example:	inc=fingerprint inclusions and needles of actinolite
Note:	Matching may take a while as generals and samples are scanned to see if any contain the unknown string (regardless of case). This parameter is ignored in the IDENTIFY procedure.

indices parameter

Form:	INDices, INDex, MATching
Context:	tabulate parameter
Usage:	tab IND tabulates TM, CM, OPM and IM matching indices.

ioxygen parameter

Form:	IOXygen
Def:	This variable contains the threshold value for ignoring oxygen in MATCH and IDENTIFY. If the sum of the unknown compositions falls below the threshold, then oxygen is ignored. For example, to find all minerals with a composition of 10% < SO4 < 15% enter: Weight SO4=10-15 IOXygen=95 Oxygen should be ignored as other oxides would undoubtedly exist and its value is set too low. If the amount of oxygen is known then IOXygen can be nulled, e.g., to match minerals with a composition of 10% < O < 15% enter: Weight O=10-15 IOXygen=null Normally IOXygen is left at its default value. When a complete unknown composition is entered (sum=100%) then oxygen is not ignored, if incomplete (sum<95%) it is ignored.
Context:	GemIdent variable accessible anytime
Usage:	IOX displays value IOX=(threshold) assigns value
Units:	90% - 100%, NULL

Default: 95%

lcutoff variable

Form: LCUTOFF
Context: GemIdent variable accessible anytime
Def: All gem divisions CLASSified with an equal or higher LEVEL than this level cutoff variable are not MATCHed nor IDENTIFied. Normally gem species or varieties are of interest, not higher classified divisions.
Usage: LCUTOFF displays value
LCUTOFF=(level) assigns value
(level): TOp, Mineral, TYpe, CLass, Family, SUPer-group, Group, SUB-Group, SEries, End-member, SPecies, SUB-Species, Polytypes, Variety, NULL
Default: LCUTOFF=group

length parameter

Form: LENgth
Context: tabulate parameter
Def: The length parameter sets the width (in characters) of the next parameter to be tabulated. If the length is not specified, a default value is used. The length specification affects only:

Parameter	Minimum	Default	Maximum
Blank	1	7	130
Division	8	20	81
Formula	7	33	100
Inclusions	7	33	130
Locality	8	53	130
Name	4	20	40
Occurrence	10	53	130
Proportion-basis	5	10	40
Remarks	7	53	130
Source	6	53	130

Usage: tab (LEN (len)) (par) tabulates the parameter in a column with the specified length

level parameter

Form LEVel
Def: A gem DIVISION is assigned its level in the classification hierarchy via the CLASSIFY

command. The TREE command displays the level of divisions and the CLASSIFY command sets them. MATCHing and IDENTIFYing can be restricted to divisions below a given level via the LCUTOFF command. A division level can be one of: top, type, class, family, super-group, group, sub-group, series, end-member, species, sub-species, polytypes and variety.

Context: tabulate parameter
Usage: tab LEV tabulates value

list parameter

Form: LIST
Context: GemIdent command available anytime
Usage: LIST lists all terms that may be EXPLAINed
Note: The BREAK key will stop the listing

locality parameter

Form: LOCality, LOCation
Def: the geographic regions where gems are found.
Context: General, sample and unknown data; tabulate parameter
Usage:

LOC	displays value
LOC=(locality)	assigns value
tab (LENgth (len)) LOC	tabulates value with specified length

(len): minimum=9, default=53, maximum=130
Units: 0 - 160 characters (for general and sample)
0 - 20 characters (for unknown)
Ex: loc=Nevada U.S.A. Minas Gerais,-
Brazil
Note: A dash designates the continuation of the same input line. Matching may take a while as generals and samples are scanned to see if any contain the unknown string (regardless of case). This parameter is ignored for identification.

lines-per-page parameter

Form: LINes-per-page LPP
Def: the maximum number of lines tabulated on a page.
Context: tabulate parameter
Usage:

tab LPP (LPP) (pars)	tabulates (pars) on (LPP) lines per page

(LPP): minimum=10, default=60, maximum=120
(pars): parameters

match command

Form: Match
Context: GemIdent command request loop.
Usage: M finds all divisions that match the unknown within the limits entered by comparing it to all divisions in the data base. If a mineral SUBSET is in use then the unknown will be compared to all divisions in the subset. If the unknown has been CLASSIFied into a division, then only minerals within that division will be compared.

M And finds all divisions that match the unknown within the limits entered by comparing it to all divisions previously MATCHed or IDENTified. MATCH is normally used first to narrow down the possibilities, then IDENTIFY AND because IDENTIFY is much slower than MATCH.

Note: The DISPLAY, SHOW and TABULATE commands can produce various forms of information about the matched minerals. MATCH and IDENTIFY differ in that MATCH rejects all minerals that lie outside the range specified for the unknown (e.g., den=3.0-4.0), while IDENTIFY does not reject any, although it assigns lower matching indices for such minerals.

maximum parameter

Form: MAXimum
Context: tabulate parameter
Usage: tab (pars)... MAX (pars)... tabulates maximum compiled data values for the parameters specified.
Note: The default is the average compiled data.

minimum parameter

Form: MINimum
Context: tabulate parameter
Usage: tab (pars)... MIN (pars)... tabulates the minimum compiled parameter values
Note: The default is average compiled data.

mismatch command

Form:	MIsmatch
Context:	GemIdent command request loop
Usage:	MIsmatch matches all minerals in the data base that have null values for the parameters specified in the unknown.
Example:	to find all minerals with no density values, enter: unknown|density=5|save|mismatch|tabulate

MOH parameter

Form:	MOHs
Context:	General, sample, unknown data; tabulate parameter
Usage:	MOH displays value MOHs=(range) assigns value tabulate MOH tabulates value
Units:	1.0 - 10.0, a nearly logorithmic hardness scale where: 1 = talc 6 = orthoclase 2 = gypsum 7 = quartz 3 = calcite 8 = topaz 4 = fluorite 9 = corundum 5 = apatite 10 = diamond
Example:	moh=4.5 - 5.0

mrecords command

Form:	MRECords
Context:	GemIdent command available anytime
Usage :	MREC (prefix) lists the record number, number of samples and generals of minerals with names starting with (prefix)
Note:	(prefix) may be a mineral name for which the above information is desired. Hitting the BREAK key will stop the listing.

n parameter

Form:	N
Def:	The index of refraction for isotropic minerals. Use RFR for unknown optical character.
Context:	General, sample and unknown data; tabulate parameter
Usage:	N displays value N=(range) assigns value

	tabulate N	tabulates value
	tabulate RIs	tabulates N, NOM, NEP, NAL, NBE and NGA
	tabulate RFR	tabulates RFR
Units:	1.3 - 10.0	
Example:	n=1.594	
Rules:	1) N implies optical-character=isotropic.	
	2) Optical-character implies symmetry=cubic.	
	3) N implies birefringence=0.0.	

n(alpha) parameter

Forms:	N(Alpha), NALpha	
Def:	the index of refraction corresponding to the X vibration direction in a biaxial mineral. Use RFR for unknown direction.	
Context:	General, sample & unknown data; tabulate parameter	
Use:	NAL	displays value
	NAL=(range)	assigns value
	tabulate NAL	tabulates value
	tabulate RIs	tabulates N, NOM, NEP, NAL, NBE and NGA
	tabulate RFR	tabulates RFR
Example:	n(alpha)=1.72-1.75	
Rules:	1) NAL implies optical-character=biaxial.	
	2) 0.0 <= birefringence <= NGA-NAL	
	3) a) (NGA-NBE) < (NBE-NAL) implies optical-sign=negative	
	b) (NGA-NBE) > (NBE-NAL) implies optical-sign=positive	
	4) 1.3 <= NAL <= NBE <= NGA <= 10.0	

n(beta) parameter

Forms:	N(Beta), NBEta	
Def:	the index of refraction corresponding to the Y vibration direction in a biaxial mineral. Use RFR for unknown direction.	
Context:	General, sample and unknown data.	
Use:	NBE	displays value
	NBE=(range)	assigns value
	tabulate NBE	tabulates value
	tabulate RIs	tabulates N, NOM, NEP, NAL, NBE and NGA
	tabulate RFR	tabulates RFR
Example:	n(beta)=1.495	
Rules:	1) NBE implies optical-character=biaxial.	
	2) (NGA-NBE) < (NBE-NAL) implies optical-sign=negative	
	(NGA-NBE) > (NBE-NAL) implies optical-sign=positive	

3) 1.3 <= NAL <= NBE <= NGA <= 10.0

n(epsilon) parameter

Forms:	N(Epsilon), NEPsilon, EPSilon		
Def:	the index of refraction corresponding to the extraordinary vibration direction in a uniaxial mineral. Use RFR for unknown direction.		
Context:	General, sample and unknown data; tabulate parameter		
Usage:	NEP	displays	value
	NEP=(range)	assigns	value
	tab NEP	tabulates	value
	tab RIs	tabulates	N, NOM, NEP, NAL, NBE and NGA
	tab RFR	tabulates	RFR
Example:	n(epsilon)=1.65		
Rules:	1) NEP implies optical-character=uniaxial.		
	2) 0.0 <= birefringence <= NEP-NOM		
	3) NEP>NOM implies optical-sign=negative NEP<NOM implies optical-sign=positive		
	4) 1.3 <= NEP <= 10.0		

n(gamma) parameter

Forms:	N(Gamma), NGAmma		
Def:	the index of refraction corresponding to the Z vibration direction in a biaxial mineral. Use RFR for unknown direction.		
Context:	General, sample and unknown data; tabulate parameter		
Usage:	NGA	displays	value
	NGA=(range)	assigns	value
	tab NGA	tabulates	value
	tab RIs	tabulates	N, NOM, NEP, NAL, NBE and NGA
	tab RFR	tabulates	RFR
Example:	n(gamma)=1.62-1.67		
Rules:	1) NGA implies optical-character=biaxial.		
	2) 0.0 <= birefringence <= NGA-NAL <= 10.0		
	3) (NGA-NBE) < (NBE-NAL) implies optical-sign=negative (NGA-NBE) > (NBE-NAL) implies optical-sign=positive		
	4) 1.3 <= NAL <= NBE <= NGA <= 10.0		

n(omega) parameter

Forms:	N(Omega), NOMega, OMEga

Def: the index of refraction corresponding to the ordinary vibration direction in a uniaxial mineral. Use RFR for unknown direction.

Context: General, Sample, Tabulate and Unknown parameter

Usage:

NOM	displays value
NOM=(range)	assigns value
tab NOM	tabulates value
tab RIs	tabulates N, NOM, NEP, NAL, NBE and NGA
tab RFR	tabulates RFR

Example: n(omega)=1.59

Rules:
1) NOM implies optical-character=uniaxial.
2) 0.0 <= birefringence <= NEP-NOM <= 10.0
3) NEP > NOM implies optical-sign=negative
   NEP < NOM implies optical-sign=positive
4) 1.3 <= NEP <= 10.0

name parameter

Form: NAMe

Def: The name of a mineral or accepted name of a synonym.

Context: mineral, synonym and unknown data; tabulate parameter

Usage:

NAM	displays value
NAM=(name)	assigns value
tab (LEN (len)) NAM	tabulates value with specified length

(len): minimum=4, default=20, maximum=40

Example: name=calcite

Note: This is the only way to rename a mineral. The new name cannot already exist. If it does then use the MERGE command. This facility can be used in the event that a mineral name has been previously spelled incorrectly. Any blanks in a name are converted to hyphens ("-") and the entire name is changed to upper case.

nulls parameter

Form: NULL

Context: a data or variable value

Usage:

(par)=NULL	erases the entire parameter's value(s)
(par)=NULL,	erases the parameter's first value
(par)=,NULL	erases the parameter's second value

Example: density=null

spectra= , , ,null,null the fourth and fifth bands are erased while the first three are left unchanged

occurrence parameter

Form:	OCCurrence
Def:	the geological environment in which the gem has been found.
Context:	General, sample and unknown data; tabulate parameter
Usage:	OCC displays value OCC={occurrence} assigns value tab (LEN {len}) OCC tabulates value with specified length
{len}:	minimum=10, default=53, maximum=130
Units:	0 - 160 characters (for general and sample) 0 - 20 characters (for unknown)
Example:	occ=In pegmatites along with lithium-bearing minerals
Note:	Matching may take a while as generals and samples are scanned to see if any contain the unknown string (regardless of case). This parameter is ignored for identification.

of parameter

Form:	OF
Context:	tabulate parameter
Usage:	tab (pars)... OF (gem)... tabulates parameters for specified gems
Note:	OF must be the last TABULATE parameter. If it is not specified then the parameters will be tabulated for all MATCHed or IDENTified minerals.
Example:	tabulate density formula of kunzite hiddenite

OPM parameter

Form:	OPM
Def:	the other properties matching (OPM) index indicates how well an unknown matches a mineral based on properties other than composition: absorption spectra, CMColour, density, dispersion, fluorescence, Mohs hardness, optical character, optical sign, pleochroism, refractive indices, symmetry and unit cell dimensions.
Context:	tabulate parameter
Usage:	tab OPM tabulates value

optical-character parameter

Form:	OPTICAL-Character, OPCharacter	
Context:	mineral data; tabulate parameter	
Usage:	OPC	displays it
	OPC=(Uniaxial Biaxial Isotropic)	assigns it
	tabulate OPC	tabulates it in "+-" column

Rules:
1) a) dichroism implies opc=uniaxial
   b) pleochroism implies opc=biaxial
2) a) N implies opc=isotropic
   b) NOM, NEP imply opc=uniaxial
   c) NAL, NBE, NGA imply opc=biaxial
3) a) cubic symmetry implies opc=isotropic and vice versa
   c) orthorhombic, monoclinic & triclinic symmetries imply opc=biaxial
   d) tetragonal, trigonal & hexagonal symmetries imply opc=uniaxial

optical-sign parameter

Form:	OPTICAL-Sign, OPSign	
Context:	mineral and unknown data; tabulate parameter	
Usage:	OPS	displays value
	OPS=(Plus Positive + Minus Negative -)	assigns value
	tabulate OPS	tabulates value

Rules:
1) NEP > NOM implies ops=negative
2) NEP < NOM implies ops=positive
3) NGA-NBE < NBE-NAL implies ops=negative
4) NGA-NBE > NBE-NAL implies ops=positive

Note: "-" cannot be the last character as this is the line continuation symbol. i.e, one can enter "-/+" but not "+/-". If a mineral has multiple optical signs, both must be specified.

output variable

Form:	OUTPUT	
Def:	variable which defines where DISPLAY, SHOW and TABULATE output is to be sent.	
Context:	GemIdent variable accessible anytime	
Syntax:	OUTPUT	displays value
	OUTPUT=Terminal	output sent to terminal screen
	OUTPUT=File	output appended to file $P.MIN

OUTPUT=Printer output sent to printer
Default: output=terminal
Note: Before using GemIdent, the DEL $P.MIN command will delete the old contents of the $P.MIN file. GemIdent creates it when it begins.

oxides parameter

Form: OXides
Context: General, sample and unknown weight parameter
Usage: weight OXides list the composition in oxide form
Note: Internally, GemIdent stores compositions in elemental form. This means GemIdent loses information about how much oxygen is associated with any particular element. It therefore assumes as much oxygen as possible was associated with an element. If one entered "w FeO=10|w Fe2O3=10" then "w ox" will produce invalid results.

pleochroic-colour(alpha) parameter

Forms: PLEOCHROIC-COLOUR(Alpha), PCAlpha
Def: The colour in thin section corresponding to the X vibration direction. If the vibration direction is unknown, use the PLEOCHROISM parameter.
Context: General, sample and unknown data; tabulate parameter
Usage:

PCA	displays value
PCA=({colour})	assigns value for samples
PCA=({colour}),...6x	assigns value for generals & unknowns
tab PCA	tabulates value
tab PLEOCHROISMS	tabulates PCA, PCB and PCG

{colour}: See COLOUR-ENTRY rules
Example: pca=red
Rules: Pleochroic-colour(alpha) implies optical-character=biaxial.

pleochroic-colour(beta) parameter

Forms: PLEOCHROIC-COLOUR(Beta), PCBeta
Def: The colour in thin section corresponding to the Y vibration direction. If the vibration direction is unknown, use the PLEOCHROISM parameter.
Usage:

PCB	displays value

	PCB=({colour})	assigns value for samples
	PCB=({colour}),...6x	assigns value for generals & unknowns
	tab PCB	tabulates value
	tab PLEOCHROISMS	tabulates PCA, PCB and PCG
{colour}:	See COLOUR-ENTRY rules.	
Synonym:	PCBeta	
Example:	pcb=dark blue	
Rules:	Pleochroic-colour(beta) implies optical-character=biaxial.	

pleochroic-colour(gamma) parameter

Forms:	PLEOCHROIC-COLOUR(Gamma), PCGamma	
Def:	The colour in thin section corresponding to the Z vibration direction. If the vibration direction is unknown, use the PLEOCHROISM parameter.	
Usage:	PCGamma	displays value
	PCGamma=({colour})	assigns value for samples
	PCG=({colour}),...6x	assigns value for generals & unknowns
	tabulat PCGamma	tabulates value
	tabulat PLEOCHROISMS	tabulates PCA, PCB and PCG
{colour}:	See COLOUR-ENTRY rules.	
Example:	pcg=pale yellow, orange	
Rules:	Pleochroic-colour(gamma) implies optical-character=biaxial	

pleochroism parameter

Form:	PLEochroism, PLC	
Def:	the phenomenon whereby a mineral shows different colours for light vibrating parallel to the X, Y or Z vibration directions. For specific vibration directions, use the PCA, PCB and PCG parameters. When the directions are unknown, use the pleochroism parameter.	
Context:	unknown data; tabulate parameter	
Syntax:	PLEochroism	displays value
	PLE={colour},...up to 6 times	assigns value
	tabulate PLEochroism	tabulates value
	tabulate PLEOCHROISMS	tabulates PCA, PCB and PCG
{colour}:	see the COLOUR-ENTRY rules	
Example:	pleochroism=red, light red, orange	

Rules: Pleochroism implies optical-character=biaxial.

pleochroisms parameter

Forms: PLEOCHROISMS, PLCS
Def: PCA, PCB and PCB
Context: tabulate parameter
Usage: tab PLCS tabulates PCA, PCB and PCG
tab tabulates PLC

proportion-basis parameter

Forms: PROPORTION-Basis, PBAse, PBAsis
Def: list of elements on which the calculation of atomic proportions are based. PSU should also be assigned.
Context: mineral data; tabulate parameter
Usage: PBA displays list
PBA=(mnem)... puts elements in list
tab (LEN (len)) PBA tabulates list with specified length
(mnem): element mnemonics in any case, i.e., h, fe
(len): minimum=5, default=10, maximum=40
Example: pbasis=o h f ca pbasis=o,h,f,ca
Note: The elements on which the proportion are based will be indicated with an "*" (asterisk) in the proportion basis column produced by the DISPLAY command.

proportion-sum parameter

Forms: PROPORTION-Sum, PSUm
Def: the formula sum of the elements that form the PROPORTION-Basis
Context: mineral and unknown data; tabulate parameter
Usage: PSU displays value
PSU=(range) assigns value
tab PSU tabulates value
Example: psum=12
Note: The sum of the atomic proportions of all the elements of a mineral will be shown on the bottom of the atomic proportions column in the sample and compiled output produced by the DISPLAY command.

range parameter

Context: most numeric inputs
(range): For GENERAL numeric parameters:

(blank spaces) leave min and max values unchanged

NULL erase min and max values
10 assign 10 as min and max values
10-20 assign 10 as min and 20 as max values

For SAMPLE and MINERAL numeric parameters:
(blank spaces) leave value unchanged

NULL erase value
10 assign 10 as value
10-20 assign average of 15 as value

For UNKNOWN numeric parameters:
(blank space) leave min and max values unchanged

NULL erase min and max values
10 assign 9.9 as min and 10.1 as max values (+/- 1%)
10-20 assign 10 as min and 20 as max values

Examples: density
density=3.4
density=null
density=3-4

records command

Form: RECords
Context: tabulate parameter
Usage: tab REC tabulates the general, mineral, sample and synonym record numbers.
Note: Compiled data have the same record numbers as mineral data. The GREC, MREC, SREC and YREC commands also display record numbers.

refractive-indices parameter

Forms: REFractive-indices, RFR, RIs
Def: The N, NAL, NBE, NGA, NOM, NEP commands apply for refractive indices of known orientation while the RFR parameter may be used when the orientation is not known.
Context: unknown data; tabulate parameter
Usage:

REF	displays value
REF={range},({range}),({range})	assigns value
tabulate RFR	tabulates RFR
tabulate RFRS	tabulates N, NOM, NEP, NAL, NBE & NGA

remarks parameter

Form:	REMarks
Context:	General, sample, synonym and unknown data, tabulate parameter
Usage:	REM displays value REM=(remarks) assigns value tab (LEN (len)) REM tabulates value with specified length
(len):	minimum=7, default=53, maximum=130
Example:	rem=No chemical data available for this gem stone.
Note:	Synonym remarks are displayed whenever the synonym is referenced. Matching may take a while as generals and samples are scanned to see if any contain the unknown string (regardless of case). This parameter is ignored for identification.
Units:	0 - 240 characters for general remarks 0 - 160 characters for sample remarks 0 - 500 characters for synonym remarks 0 - 20 characters for unknown remarks

requests variable

Form:	REQuests
Context:	GemIdent variable accessible anytime
Usage:	REQ displays value REQ=ON GemIdent will request data for all unknown parameters. User input is assumed to be data. To issue a command, prefix the command with a '#'. REQ=OFf GemIdent will not request data for unknown parameters. User input is assumed to be commands. The '#' prefix is not necessary.
Note:	The ENTER key must be pressed twice after this command. Requests made by GemIdent take the following form: request"default"? The "request" displays the input value/command required while the "default" displays the value/command that will be input if nothing is entered. One can append input to the default via the @ symbol. Command requests normally have no defaults, while data requests usually have the current value as default.

samples parameter

Form:	SAMples
Context:	tabulate parameter
Usage:	tab SAM (pars)... tabulates sample data for the specified parameters
Note:	Sample data can also be DISPLAYed and SHOWn.

save command

Form:	SAVE
Context:	general, mineral, sample, synonym and unknown command
Usage:	SAVE stores ADDed or EDITed data to disk and returns to the previous request loop. UNKNOWN data is not saved.
Note:	A break will also cause GemIdent to return to the previous request loop but WITHOUT UPDATING THE DATA BASE.

show command

Form:	Show	
Context:	GemIdent command request loop	
Usage:	S Compiled (Generals)	shows compiled / mineral and possibly
	S (Samples) (mineral)...	sample/general data for specified minerals
	S General (general)	shows mineral / general data for specified generals. See GRECords.
	S Sample (sample)	shows mineral/sample data for specified samples. See SRECords.
	S Matched	shows compiled / mineral data for MATCHed/IDENTified minerals
	S Unknown	shows unknown data
Note:	The date displayed is the date data was last modified. For compiled data, minimum, average and maximum parameter values are shown. The standard deviations of compositions are shown only when more than five analyses have been used. For general data, minimum and maximum parameter values are shown. Show respects the WIDTH variable.	

showwhat variable

Form:	SHOWWhat
Context:	GemIdent variable available anytime. Controls the output produced
Use:	This variable controls the output produced by the SHOW command.
Default:	SHOWW=BOTH
Usage:	SHOWW displays value SHOWW=Both SHOW will display both full and empty parameters SHOWW=Full SHOW will display full parameters SHOWW=Empty SHOW will display empty (null) parameters. Useful in listing of missing data.

sort command

Form:	SORT
Context:	GemIdent command available anytime
Usage:	SORT Sorts the MATCHed/IDENTified minerals in alphabetical order.

source parameter

Form:	SOUrce
Context:	general, sample, synonym and unknown data; tabulate parameter
Usage:	SOUrce displays value SOUrce=(source) assigns value. It should include the journal's name, volume and page number; and in case of books, author and year of publication with abbreviated title. tab (LEN (len)) SOU tabulates value with specified length
(len):	minimum=6, default=53, maximum=130
Units:	0-160 characters (for general or sample) 0- 20 characters (for unknown)
Example:	sou=Gems & Gemol. v.21, 70-79.
Note:	The GREC, MREC and SREC command will also list sources. Source is a required parameter. Matching may take a while as generals and samples are scanned to see if any contain the unknown string (regardless of case). This datum is ignored for identification.

srecords command

Form: SRECords
Context: GemIdent command available anytime
Usage: SREC (mineral) lists the record numbers and sources of all samples for a mineral. A BREAK will stop the listing. Useful prior to the DELETE sample, DISPLAY sample, EDIT sample and SHOW sample commands which require the sample record number.
Example: srec dioptase

status command

Form: STATus
Context: GemIdent command available anytime
Usage: STAT prints out the following information about the state of the data base and the user:

1) number of mineral, sample and general records in the data base
2) number of sample, general and compiled records that need to be displayed
3) number of uncompiled minerals, number of synonyms
4) whether the general and sample data are available or not.
5) values of user variables

stop command

Forms: EXIT, QUIT, STop
Usage: ST terminate the program.
Note: Data added or edited without being SAVEd will be lost. IF SYStem is used to invoke DOS then the DOS exit command will return the user to GemIdent.

subset command

Form: SUBSET
Context: GemIdent command available anytime; tabulate parameter
Usage:

SUBSET	displays number of subset mirerals
SUBSET Load (file)	quickly loads the subset minerals pointers
SUBSET Off	empties the subset, use the entire data base

SUBSET Read	(file)	slowly read the subset mineral names
SUBSET Save	(file)	quickly saves the subset mineral pointers
SUBSET Transfer		quickly transfers the MATCHed/IDENTified minerals to the subset
SUBSET Write	(file)	slowly writes the subset mineral names
tab SUB (pars)...		tabulates parameters for the subset

Note: A subset is normally created by READing it in once, as this is slow. It is then SAVEd to a file. On subsequent occasions, it is quickly loaded rather than slowly read. Subsets have been created so that a restricted group of minerals can be examined. This may be useful for teaching purposes or when it is known that only a restricted number of minerals need be considered in a particular application. Use of subsets can cut processing time dramatically.

sum parameter

Form: SUM
Context: sample, general, unknown weight parameter; tabulate parameter
Usage: weight SUM displays the composition sum
tab SUM tabulates the composition sums

symmetry parameter

Form: SYMmetry
Context: mineral, unknown data; tabulate parameter
Usage:

SYM	displays	value
SYM={sym}...	assigns	value
tab SYM	tabulates	value

{sym}: Cubic/Isometric, Hexagonal, Monoclinic, Orthorhombic, TEtragonal, TRIClinic, TRIGonal
Example: sym=tetrag,trig,orth Could be used to list all minerals having any one of these symmetries, i.e., all uniaxial minerals.
Rules:
1) sym=cubic implies OPC=isotropic and vice versa
2) sym=orthorhombic/monoclinic/triclinic implies OPC=biaxial
3) sym=tetragonal/trigonal/hexagonal implies OPC=uniaxial

Note: If a mineral has more than one symmetry, "multiple" will be shown in DISPLAYs and TABULATions.

system command

Form:	SYStem
Context:	GemIdent command available anytime.
Usage:	SYS Go to the DOS system. Typing EXIT returns the user to GemIdent.

tabulate command

Forms:	Tabulate, Table
Context:	GemIdent command request loop
Usage:	T ({pars}|{tpars})... tabulate parameters for minerals
{pars}:	Any COMPILED, GENERAL, MINERAL, SAMPLE, SYNONYM or UNKNOWN data. Also: ANGles, BLAnk, BRILLiance, CLArity, CM, CMColours, CUT, DATA, DICHROISMS, DIMensions, EDGes, FINISH, FLUORESCENCES, LEVel, NM, NUMber, OPM, OUTline, PARents, PLEOCHROISMS, PROfile, RECord, RIs, TM, SUM
{tpars}:	ALL, AVErage, CHAracters-per-line, DEFault, GENerals, LENgth, LINes-per-page, MAXimum, MINimum, OF, SAMples, SUBset, SYNonym, UNKnown
Example:	1) t nam den w SiO2 w Al2O3 tabulates the names, densities and weights of SiO2 and Al2O3 of all MATCHed/IDENTified minerals. 2) t w K w Ca for of amazonite tabulates the formulae and weights of K and Ca for amazonite. 3) tabulate: tabulates default parameters for MATCHed/IDENTified minerals

tlist command

Form:	TLIST
Context:	GemIdent command available anytime
Usage:	TLIST lists the mineral types. See the TYPE command. A BREAK will stop the listing.

TM parameter

Form:	TM
Def:	the total matching (TM) index is calculated from the weighted average of the other indices (CM, IM, OPM). It is used to order the top 20 minerals for identification

purposes. The weighting given to each index may be changed from time to time to improve discrimination between minerals.

Context: tabulate parameter
Usage: tab TM tabulates value

transparency parameter

Form: TRAnsparency
Def: the degree to which light is transmitted
Context: general, sample and unknown data; tabulate parameter
Usage:

TRA	displays value
TRA=(value)	assigns sample value
TRA=(value)-(value)	assigns general or unknown value
tabulate TRA	tabulates value

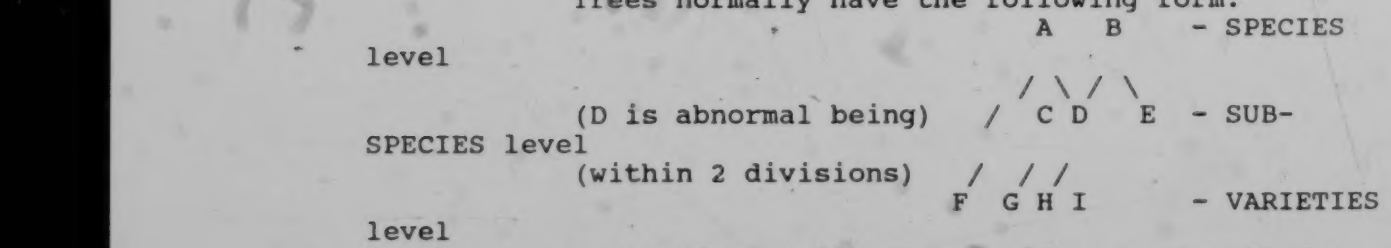
(value):

TRANSParent	TP
SEMI-TRANSParent	STP
TRANSLucent	TL
SEMI-TRANSLucent	STL
Opaque	Op

tree command

Form: TREE
Def: "trees" show a mineral's position in the classification hierarchy.

Trees normally have the following form:



GemIdent prints trees sideways. A path from the mineral to the top of the tree is shown. A few minerals, such as D above, have two possible paths upwards. For such minerals, which will be postscripted by an "*", only one path will be traced. To trace the other path, specify "alternate". Also, all the minerals one level lower will be shown. To see the minerals more than one level lower, specify "full". Note: F is considered to be one level lower than A.

Context: GemIdent command available anytime
Usage: TREE (mineral) (Full) (Alternate) shows the classification hierarchy "tree"
Example:

TREE A	TREE A FULL	TREE H	TREE H ALTER
A species	A species	A species	B species
F variety	F variety	D sub-species*	D sub-species
C sub-species	C sub-species	H variety	H variety
D sub-species	G variety		
	D sub-species		
	H variety		
	I variety		

unknown command

Form:	Unknown	
Def:	the mineral to be IDENTIFied or MATCHed	
Context:	GemIdent command request loop; tabulate parameter	
Usage:	Unknown	enables adding of unknown data
	Unknown Edit	enables editing of unknown data
	tab UNK (pars)...	tabulates unknown (min/max) parameters
Note:	GemIdent will enter the "Unknown input" request loop if REQUEST=off, or will request all the unknown parameters if REQUEST=on.	

variables variable

Form:	VARiables
Def:	The variable affect the behaviour of GemIdent. They are: CASE, ECHO, IOXYGEN, LCUTOFF, OUTPUT, PAUSE, SHOWWHAT, WCUTOFF WIDTH, ZERO
Context:	GemIdent command available anytime
Usage:	VAR displays the values of the variables

vertical bar parameter

Form:	|
Def:	the vertical bar symbol is used to separate multiple commands on one input line. GemIdent will place a "|:" before the next command being read in from such a line.
Context:	GemIdent symbol command available anytime
Usage:	{command1}|{command2} executes both commands
Example:	The following command: unknown|moh=9-10|save|match|tabulate moh name is equivalent to:

```
                unknown..... unknown data can now be
                             entered
                moh=9-10.....entry of mohs' hardness
                             for unknown
                save.........data entry for unknown is
                             complete
                match........find minerals with
                             9>=moh>=10
                tabulate moh name...table of matched minerals
                             and will cause an output
                             similar to:
                unknown|moh=9-10|save|match|tabulate moh name
                |: moh=9-10|save|match|tabulate moh name
                |: save|match|tabulate moh name
                |: match|tabulate moh name
                |: tabulate moh name
```

Note: The sequential presentation above is made so that a user is aware of which statement is being processed. This is important if one of the statements contains an error. All commands on the same input line following a command which is in error will be ignored and the message "Multiple commands ignored" will be printed.

wcutoff variable

Form: WCUTOFF
Def: the weight percentage for which elements with a lower value will be ignored (not used) in the MATCH procedure.
Context: GemIdent variable accessible anytime
Usage:

WCUTOFF	displays value
WCUTOFF=(range)	assigns value

Units: 0.0 - 5.0%

weight parameter

Form: Weight
Context: general, sample, unknown data; tabulate parameter
Usage:

W	displays weights of all elements in elemental form
W OXides	displays weights of all elements in oxide form
W NULL	erases weights of all elements
W SCALE	scales weights to sum to 100.0%
W SUM	displays the sum of the weights
W Fe2O3	displays the weight of Fe2O3

unknown..... unknown data can now be entered
moh=9-10.....entry of mohs' hardness for unknown
save.....data entry for unknown is complete
match.....find minerals with 9>=moh>=10
tabulate moh name...table of matched minerals and will cause an output similar to:

```
unknown|moh=9-10|save|match|tabulate moh name
|: moh=9-10|save|match|tabulate moh name
|: save|match|tabulate moh name
|: match|tabulate moh name
|: tabulate moh name
```

Note: The sequential presentation above is made so that a user is aware of which statement is being processed. This is important if one of the statements contains an error. All commands on the same input line following a command which is in error will be ignored and the message "Multiple commands ignored" will be printed.

wcutoff variable

Form: WCUTOFF
Def: the weight percentage for which elements with a lower value will be ignored (not used) in the MATCH procedure.
Context: GemIdent variable accessible anytime
Usage: WCUTOFF displays value
WCUTOFF=(range) assigns value
Units: 0.0 - 5.0%

weight parameter

Form: Weight
Context: general, sample, unknown data; tabulate parameter
Usage:

W	displays weights of all elements in elemental form
W OXides	displays weights of all elements in oxide form
W NULL	erases weights of all elements
W SCALE	scales weights to sum to 100.0%
W SUM	displays the sum of the weights
W Fe2O3	displays the weight of Fe2O3

W Fe2O3=(range)	ADDS the weight to Fe2O3
W Fe2O3=TRACE	is equivalent to Weight Fe2O3=0.0-1.0% for UNKNOWN
W Fe2O3=MINOR	is equivalent to Weight Fe2O3=0.1-5.0% for UNKNOWN
W Fe2O3=MAJOR	is equivalent to Weight Fe2O3=3.0-100% for UNKNOWN
W Fe2O3=NULL	erases the weights of Fe and O. This could have undesirable consequences because oxygen associated with all elements will be deleted. It is better to use form 3) and then re-enter the weights. This form may safely be used when weights entered in elemental form, i.e., w Fe=4|w Fe=null is ok.
W F1-=(range)	assigns the weight% to F and subtracts the oxygen equivalent from O.
W Mn=75ppm-80ppm	equivalent to Weight Mn=0.0075-0.0080%
tab W Fe2O3 W Mn	tabulates the weight% of Fe2O3, Mn

Note: Unlike other parameters, weight assignments are ADDED to previous values instead of REPLACING them. This is done so that a composition of FeO=5 and Fe2O3-7 could be entered. Otherwise, the amount of Fe corresponding to Fe2O3=7 would replace the previous amount. Weights will be displayed in elemental form. When samples specify a weight of TRACE, enter 0.0. The value of the CASE variable affects the processing of formulae. Weights are always in percentages, not as weight fractions and the percent symbol (%) is omitted. Weights are DISPLAYed in elemental form. The standard deviations will appear in DISPLAYs only when more than five analyses are present.

width variable

Form:	WIDTH
Def:	the width of the terminal affects the DISPLAY, SHOW and TABULATE commands
Context:	GemIdent variable accessible anytime
Syntax:	WIDTH displays value WIDTH=(width) assigns value
(width):	minimum=39, default=79, maximum=132

yrecords command

Form:	YRECords
Context:	GemIdent command available anytime
Usage:	YREC (prefix) lists all synonyms that start with the prefix
Note:	Hitting the BREAK will stop the listing

zero variable

Form:	ZERO
Context:	GemIdent variable available anytime
Usage:	ZERO displays value ZERO=Yes zeros null weights in matching ZERO=No assigns null weights a range between 0.0% and the maximum available weight which equals 100.0% minus the sum of the minimum composition sum.
Note:	When ZERO is yes, the number of matched minerals will be considerably smaller. However, minerals with incomplete data may be ignored.

For further information on the GemIdent data base please contact:

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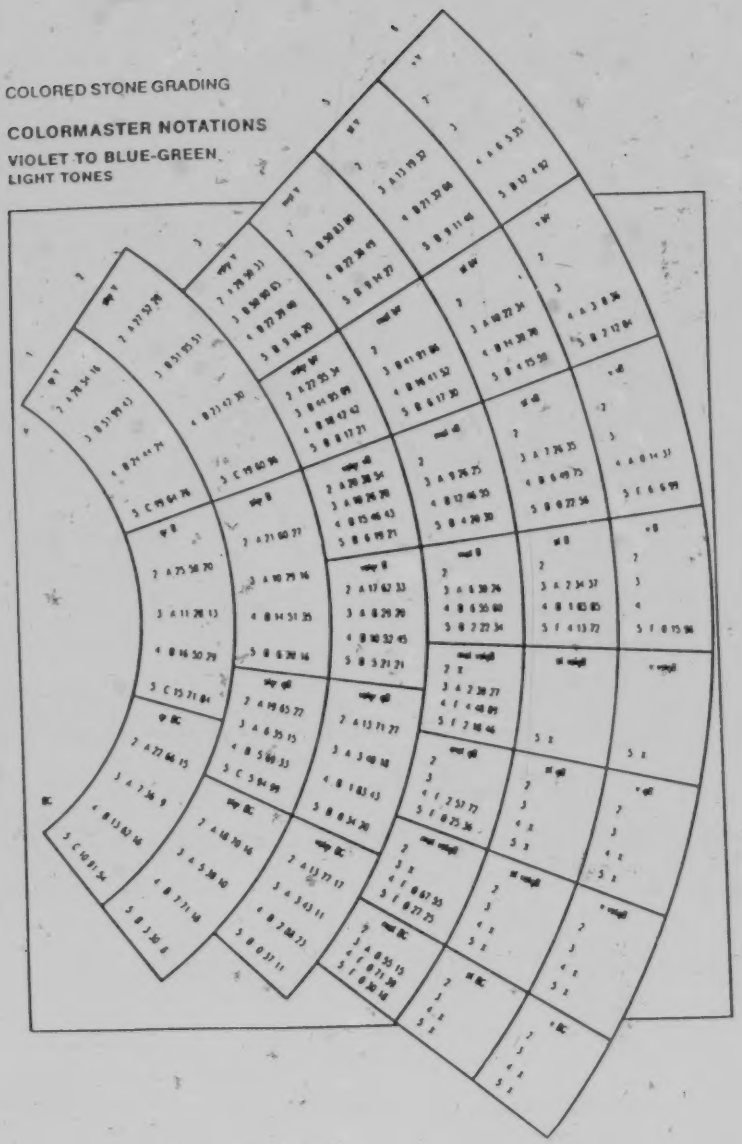
APPENDIX II: COLORMASTER CONVERSION CHARTS.

In the following pages the ColorMaster Colored Stone Grading Charts are presented (copyright permission obtained from the GIA). They provide the necessary conversions between the ColorMaster notations and the alternate abbreviation (e.g., B 2 12 84 corresponds to bV 5/6) used in this system. The numbers inside each box represent the number abbreviation for the tones (2-8), and those above the column of boxes are abbreviations for saturations (1-6). Two separate charts are available for each hue, one is for lighter tones (2-5) and the other for darker tones (5-8).

COLORED STONE GRADING

COLORMASTER NOTATIONS

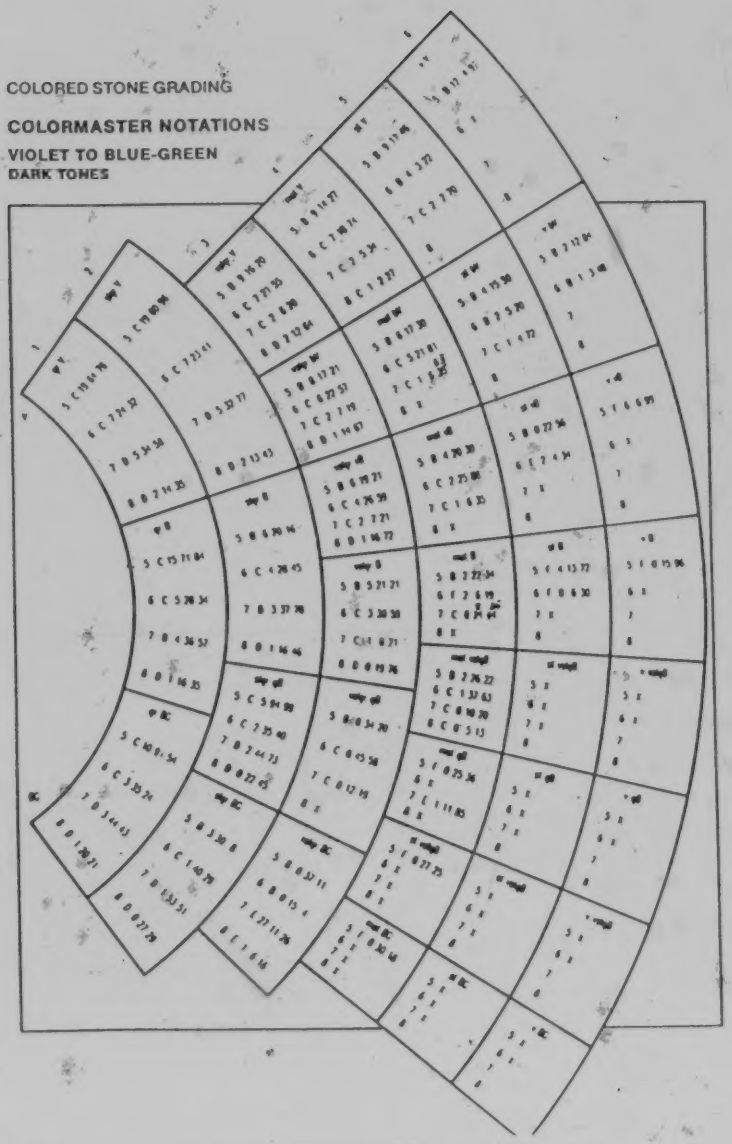
VIOLET TO BLUE-GREEN
LIGHT TONES



COLORED STONE GRADING

COLORMASTER NOTATIONS

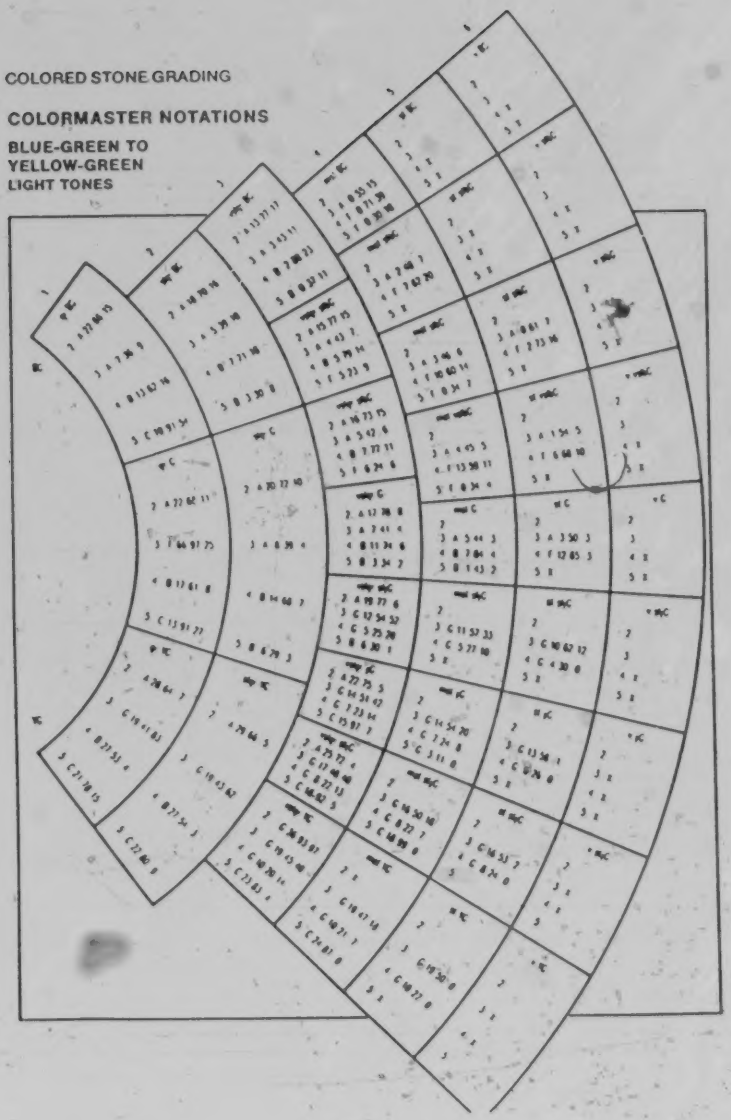
VIOLET TO BLUE-GREEN
DARK TONES



COLORED STONE GRADING

COLORMASTER NOTATIONS

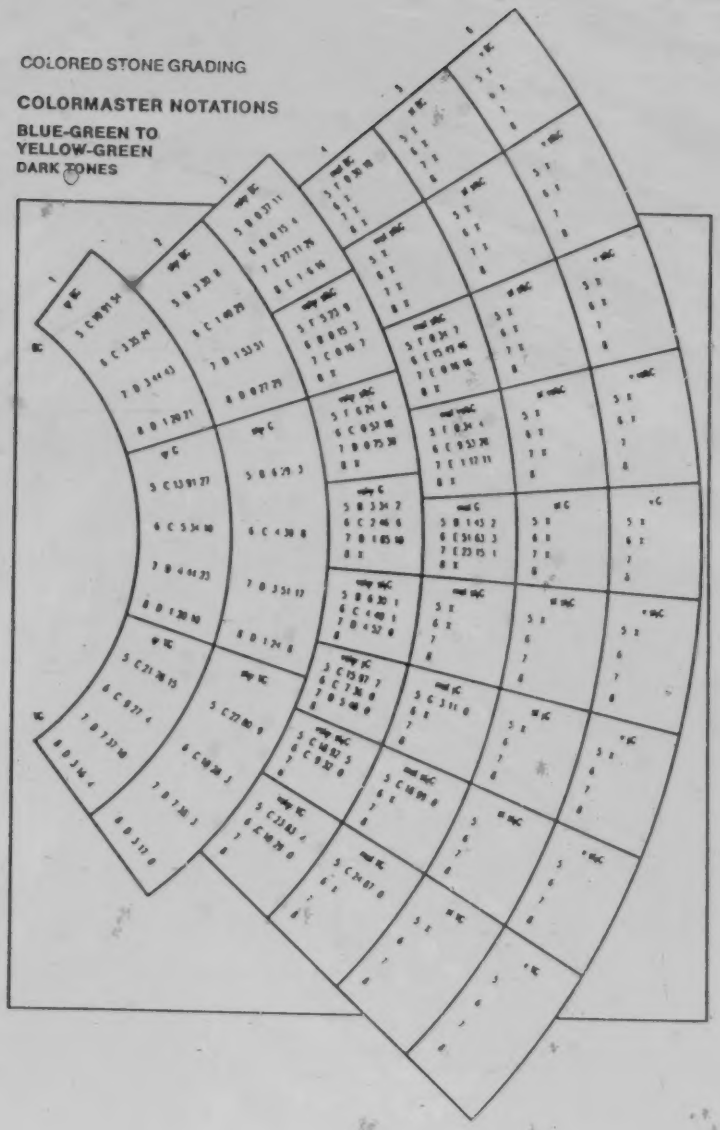
BLUE-GREEN TO YELLOW-GREEN LIGHT TONES



COLORED STONE GRADING

COLORMASTER NOTATIONS

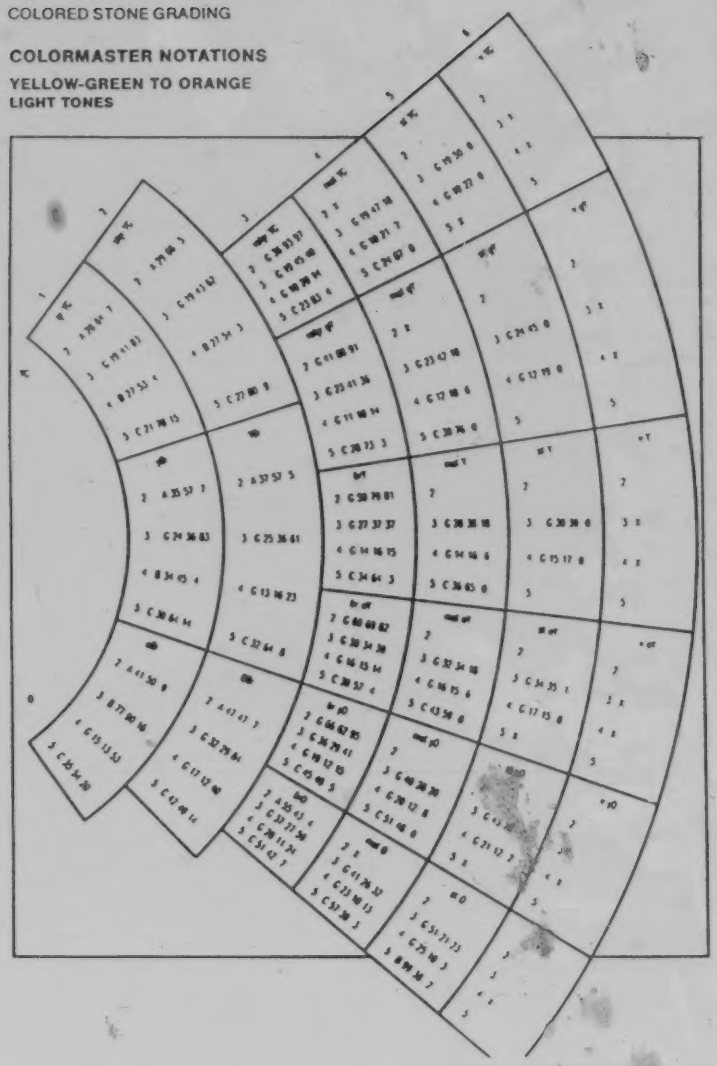
BLUE-GREEN TO YELLOW-GREEN DARK TONES



COLORED STONE GRADING

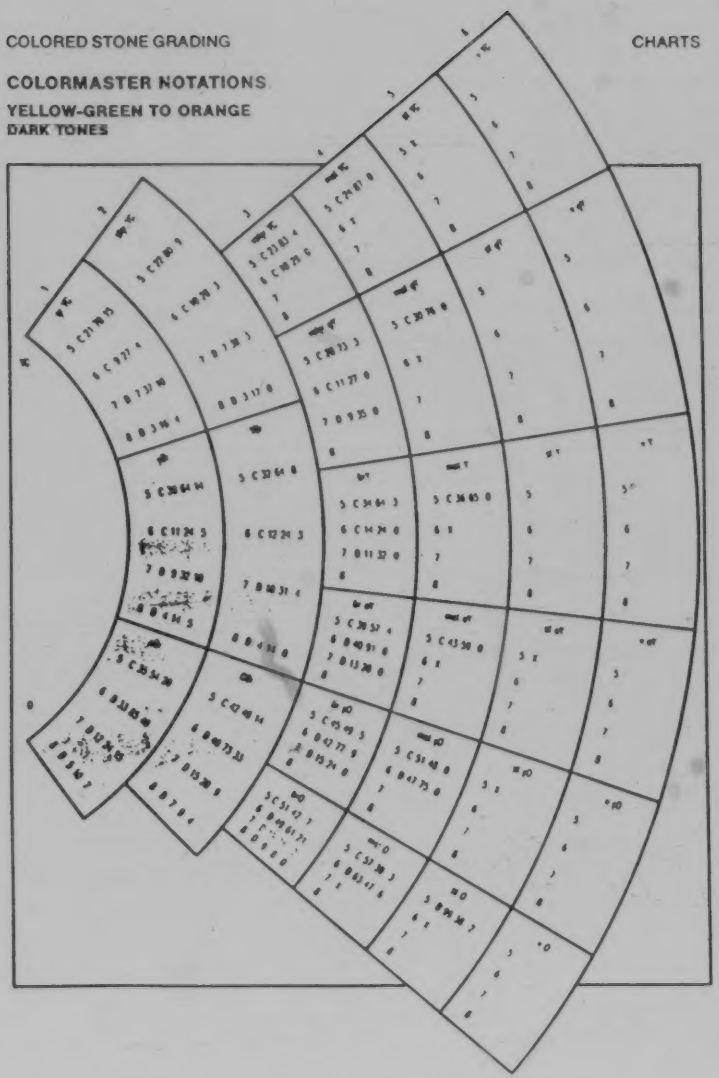
COLORMASTER NOTATIONS

YELLOW-GREEN TO ORANGE
LIGHT TONES



COLORMASTER NOTATIONS

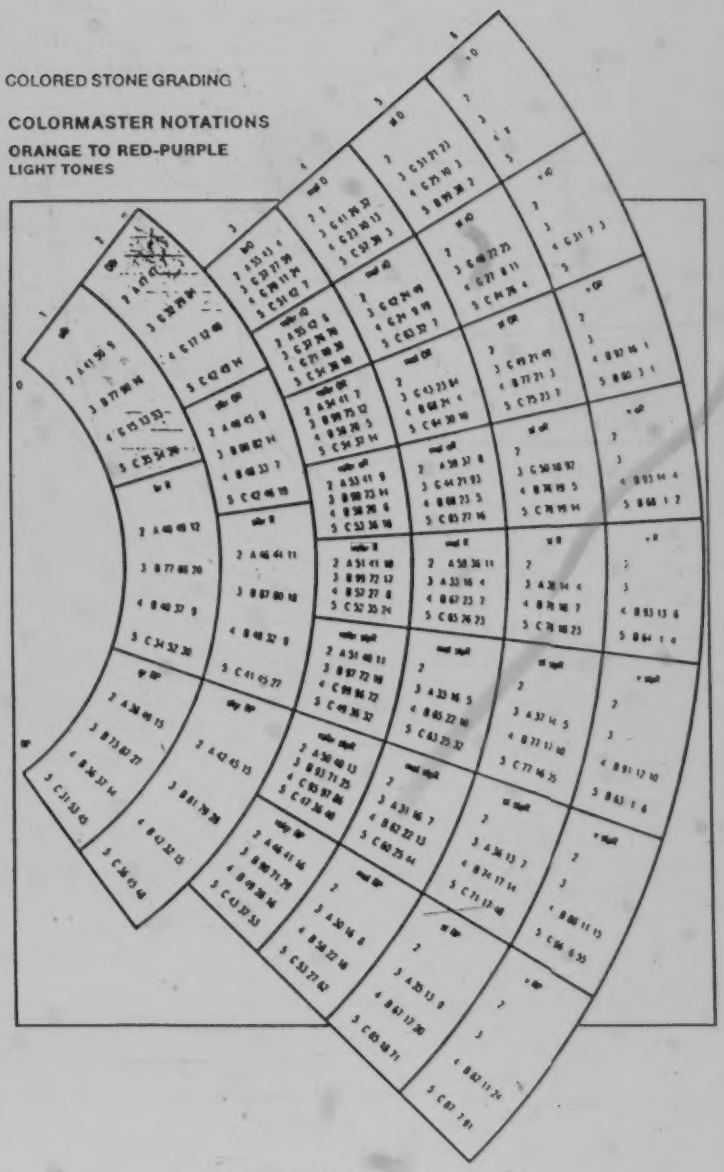
YELLOW-GREEN TO ORANGE
DARK TONES



COLORED STONE GRADING

COLORMASTER NOTATIONS

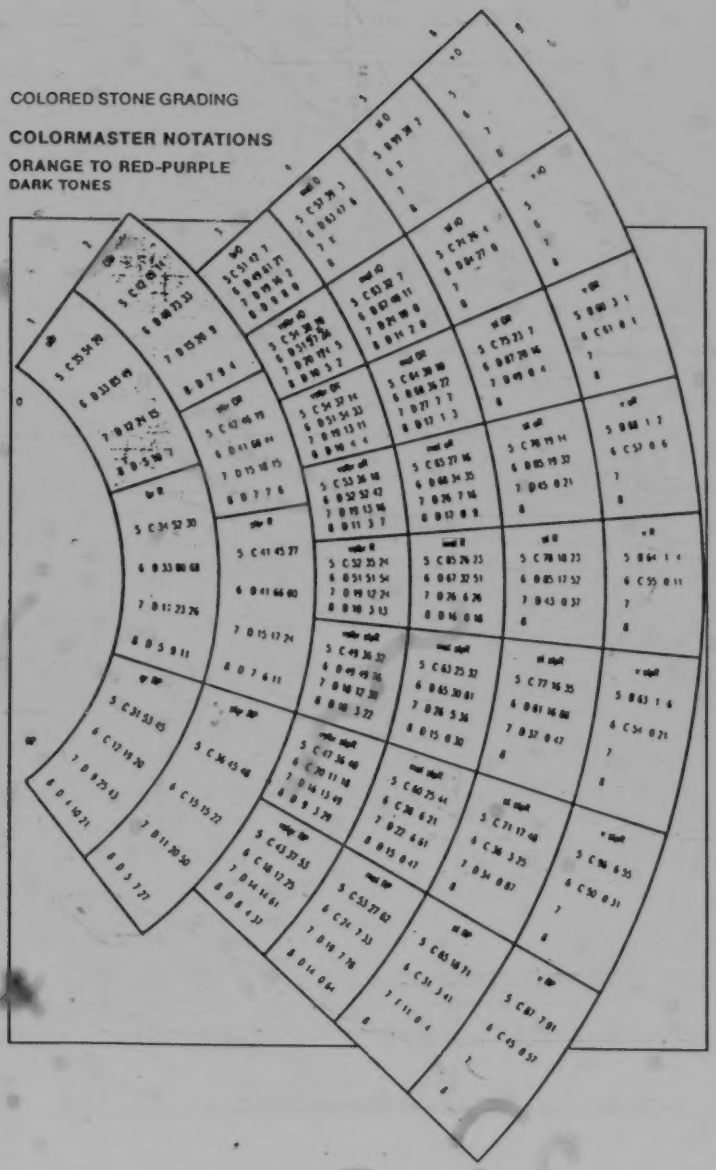
ORANGE TO RED-PURPLE
LIGHT TONES



COLORED STONE GRADING

COLORMASTER NOTATIONS

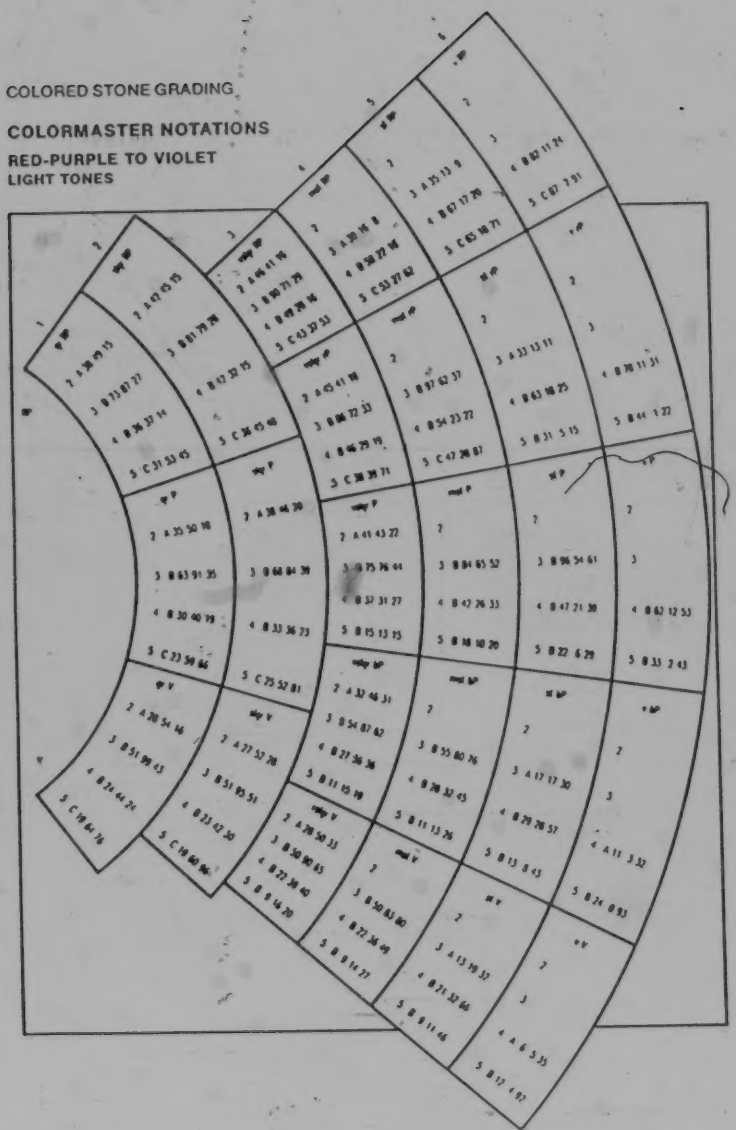
ORANGE TO RED-PURPLE
DARK TONES



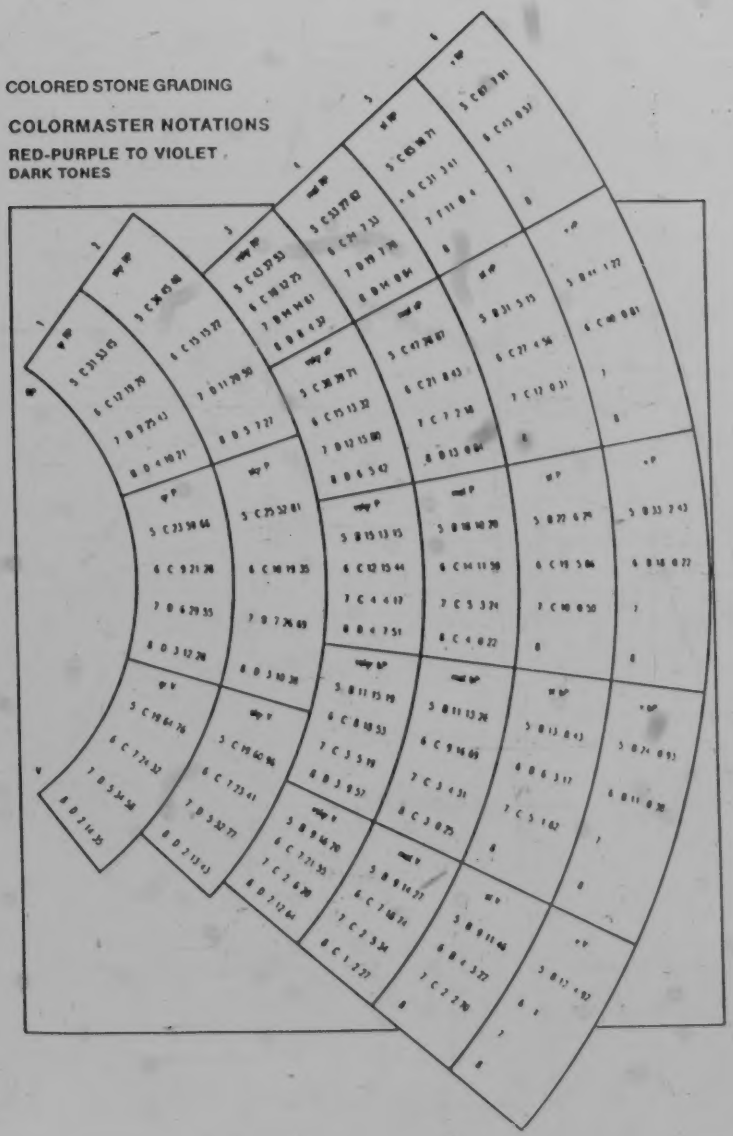
COLORED STONE GRADING

COLORMASTER NOTATIONS

RED-PURPLE TO VIOLET
LIGHT TONES



COLORED STONE GRADING

COLORMASTER NOTATIONS

RED-PURPLE TO VIOLET
DARK TONES